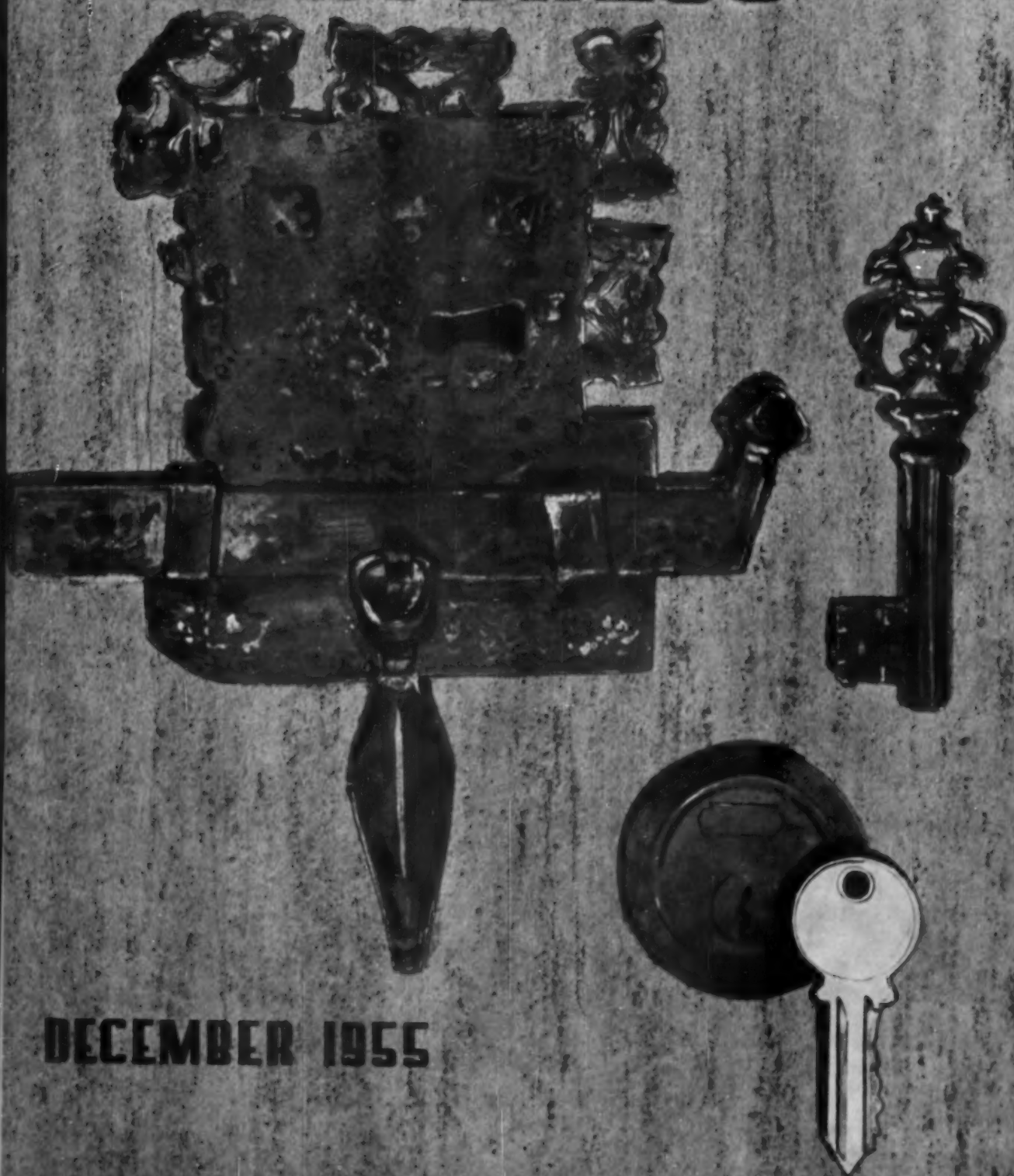
METAL PROGRESS



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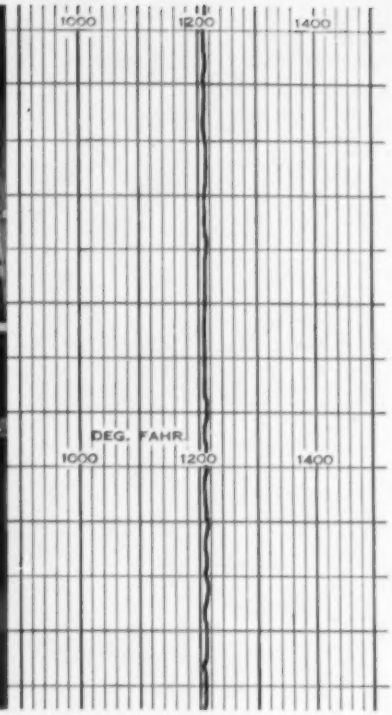

This chart demonstrates the accurate temperature control achieved by Triangle in its 'Surface' annealing furnaces.

good start, bright finish

for Triangle copper tubing. Uniform grain size and scale-free surfaces, essential for high-production drawing of copper tubing, are achieved with three 'Surface' furnaces and a DX® gas generator at Triangle Conduit & Cable Co., New Brunswick, N. J.

This 12,000 lbs./hr. heat treat installation *with automatic work* handling is right in the production line. One of the furnaces heats billets for drawing; the second continuously anneals tubing after initial drawing.

It's the third furnace, a radiant tube-heated controlled-atmosphere roller hearth type, which shows best the advantages of this 'Surface' line. It easily holds *specified grain size to 0.040 mm, and* holds temperature within ± 10°F. High-speed roof fans mean uniform heating at top speed. Finished tubing is clean, bright, ready for packaging.

New developments in heat treating like this are coming continuously from 'Surface.' Let us tell you about new heat treat equipment to increase your production of copper-base alloys and improve work quality.

Write for Bulletin H55-12

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HEAT TREATING EQUIPMENT

SURFACE COMBUSTION CORPORATION, TOLEDO 1, OHIO
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Metal Progress

Volume 68, No. 6

December . . 1955

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Powder Metallurgy in Atomic Energy

Metallurgical Problems in Design of Nuclear Power Reactors, by Vincent P. Calkins 73

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Preparation of Metal Powders for Nuclear Reactors, by P. Chiotti and H. A. Wilhelm 77

Both uranium and thorium powder may be prepared by forming the hydride and decomposing it by heating under reduced pressure. (H 10, U, Th)

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The Mechanism of Sintering of Nonvolatile Metals and Oxides, by Leslie L. Seigle and A. L. Pranatis 86

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Nickel Conservation With High-Manganese Stainless Steels, by Franklin P. Huddle 100

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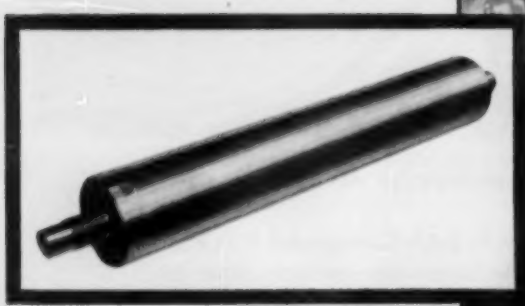
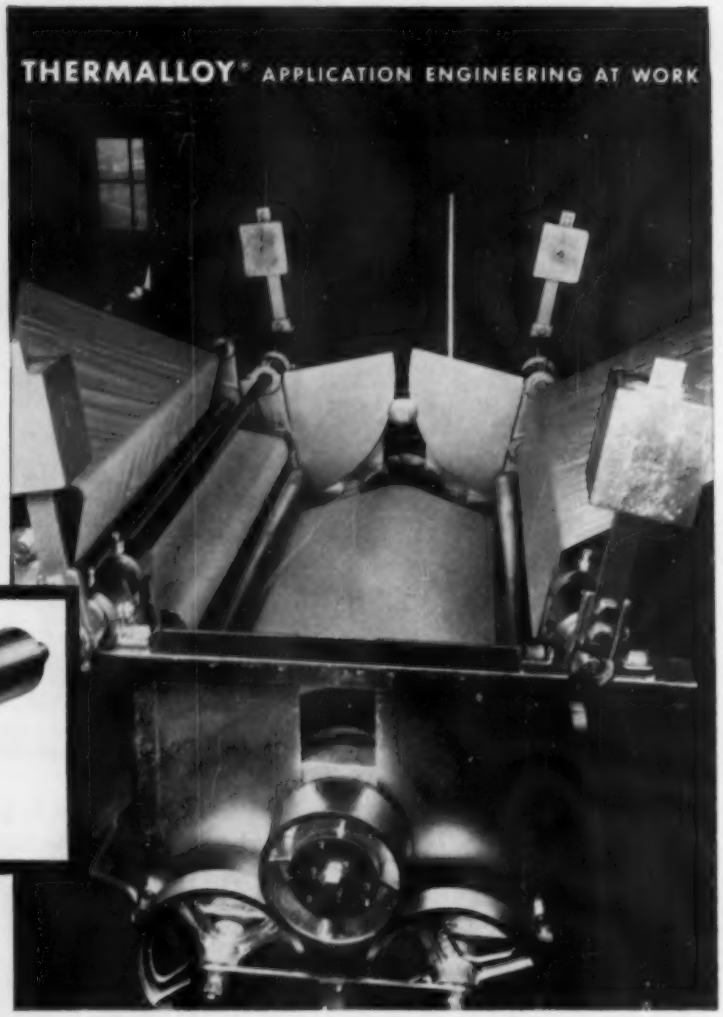
It's heat treating by another name





This singe roller is made of Thermalloy to withstand the constant high temperature of furnace gases. It is part of a Rotary Plate Cloth Singeing Machine manufactured by the American Gas Furnace Co., Elizabeth, New Jersey.

They call it cloth singeing. And, normally, you wouldn't expect to find Electro-Alloys supplying high heat-resistant Thermalloy castings to the textile industry. But, wherever high heat or abrasion is a problem, you'll find Electro-Alloys coming up with answers that give more operating economy per dollar.

In this case, the singe roller, partly inserted in a furnace, is heated to 1600° F. Cloth feeds over the hot roller and is singed. The roller must endure this constant intense heat without deforming, oxidizing or otherwise contaminating the cloth.

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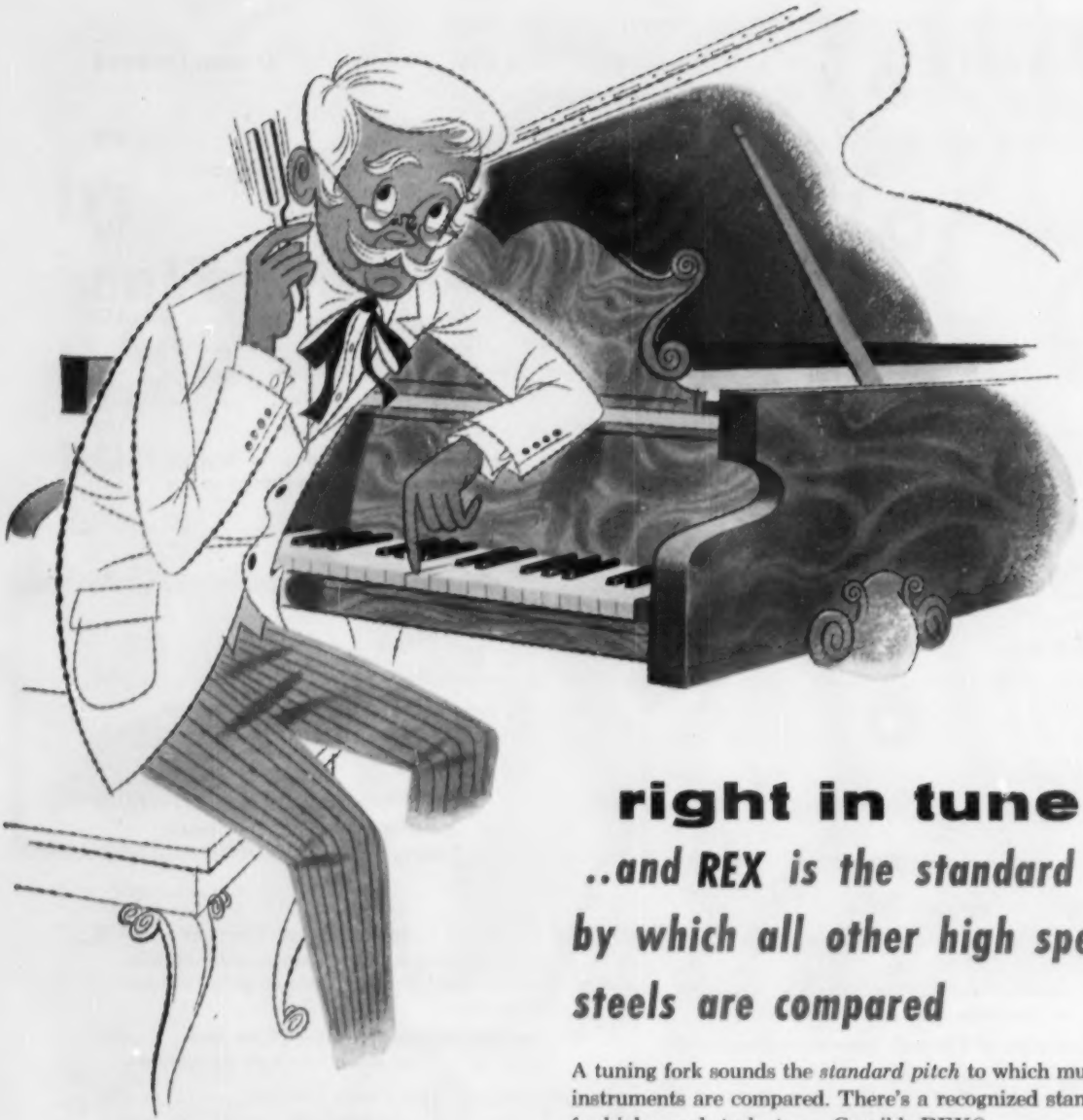
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As I was saying...

A MERRY CHRISTMAS to you and yours!

As the years rock and roll the time between one Christmas and the next grows shorter but the Merry Greetings grow more and more sincere. And that is as it should be.

We put the 37th Congress and Exposition to bed in Philadelphia with everyone singing its praises. The exhibitors were happy with the 56,953 visitors, the authors were pleased with the fine attendance at the technical sessions, the cooperating societies were happy as a lark at the success of their meetings, and the A.S.M. staff heaved a thunderous sigh of relief when every planned activity came off as scheduled. In reality, however, the opening session of the Congress and opening hour of the Show mark the end of the staff planning, because if everything is not in order by the opening – it's too late!

Even months before the curtain descended on the Philadelphia activity, plans were being evolved for the technical program and the exposition to be held in Cleveland next year – Oct. 8 through 12, 1956.

There were many pleasing activities connected with The Philadelphia Story, but there was one event that gave me a real deep-seated thrill; that was the Distinguished Service Luncheon given by the Society in honor of the 25-year members of the A.S.M., and as special guests some 200 student members from schools within a wide radius of the Friendly City. The ushers seated four 25-year men and four student members at each table. From my vantage point at the table on the stage I was able to observe the introductions and the animated conversation and discussion that took place at each table. Here was experience talking and counseling with youth, conversing with members who in 25 years would be on the other side of the table, taking their turn in passing on their experiences of the past. When the luncheon was declared adjourned one could see the firm handshakes of sincere fellowship that took place at each table. A magnificient tribute to the Distinguished Service of these ⬢ members!

Have you written to Santa yet to tell him what you want in your sock? If not, do not delay too long – the *males* are slow these days, so I am told. But whatever you want, I hope you get it. All ⬢ members have done a swell job this past year and are highly deserving – as always – of the best. In your letter to Santa you may designate me as a reference, and then forget all about it, because I'll justly praise you to the skies.

Merry Christmas!

Cordially yours,

Bill

W. H. EISENMAN, *Secretary*
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CARBURIZING

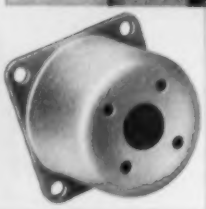
1 This is the operation for which the Leland salt bath was originally purchased. Work is heated at 1650° for 30 minutes, oil quenched and washed. A consistent, scale-free 0.005" case with surface hardness of R_{15N} 75/80 is obtained.

SIMULTANEOUS BRAZING AND CARBURIZING

2 Simultaneous brass brazing and carburizing cut cost from $79 to $13.11 per 1,000 parts, eliminated 3 handling operations, saved time. Average strength of brazed joints is 40,000 PSI. Case depth is 0.005"—0.007" with R_{15N} 80/85 surface hardness.

BRAZING

3 Ajax Salt Bath brass brazing of this assembly reduced costs from $14.20 to $9.10 per thousand—without considering the reduction in rejects from 25% to less than 1% and elimination of 3 additional treatments previously needed with copper brazing.



HARDENING

4 SAE-1050 and 1065 cold rolled parts are hardened in the same Ajax bath used for the 3 other operations. Hardened parts will bend 45° before fracturing. The "pick-up" of a superficially carburized case is not objectionable.

4 Cost-Cutting Operations with One AJAX Salt Bath

. . . that saved $37,000 the first 8 months!

Write for details outlining the G. H. Leland Inc., multi-use operation of its Ajax salt bath.

Let Ajax engineers demonstrate similar heat treating savings. You get actual proof on your own work samples in the Ajax Metallurgical Service Laboratories. No cost or obligation.

During its first 8 months on the job, this Ajax Electric Salt Bath Furnace saved $37,000 in the plant of G. H. Leland, Inc., Dayton, Ohio. This saving was figured after deducting *all* operating costs and 20% annual equipment depreciation!

Or, to put it another way, the amazing versatility of the Ajax furnace installation *enabled it to pay for itself in just a few months of use!*

Not only does the Salt Bath handle all four heat treating operations described and illustrated above . . . but the Leland model shop uses it for odd jobs as well.

Work is scale free. Distortion is no longer a problem . . . and the firm's entire parts processing has been effectively streamlined.

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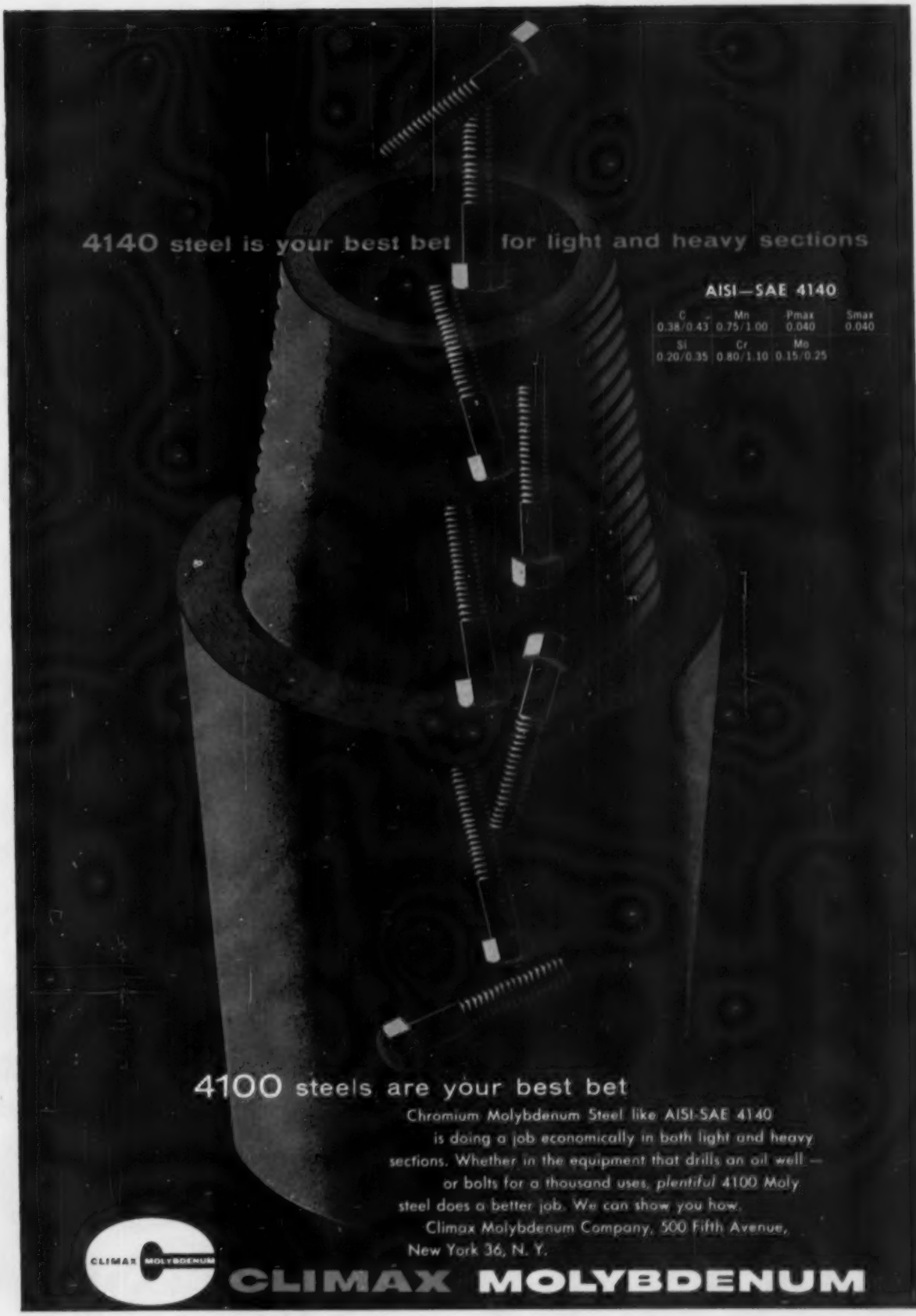
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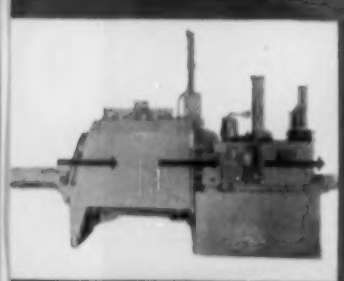
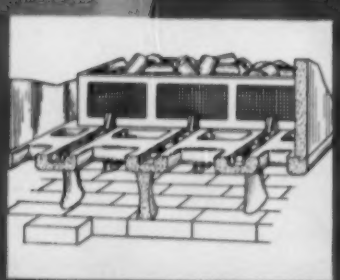


Straight-through operation eliminates charge vestibule. Work loaded directly into hot zone for safety assurance.



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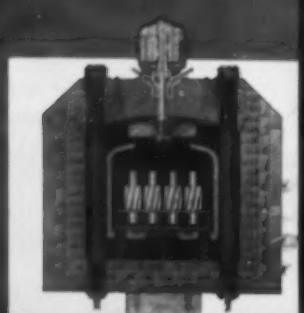

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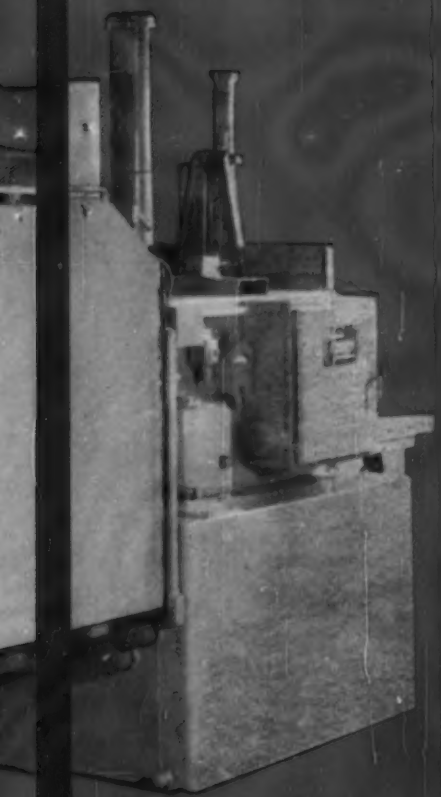

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1550 F.	1330 F.	600 lb.	62 minutes
1700 F.	1410 F.	600 lb.	98 minutes
1850 F.	1520 F.	600 lb.	127 minutes

Operating performance for the T-400A, gas-fired unit, showing normal heating rates at three operating temperatures. Tray weight is 45 lb.

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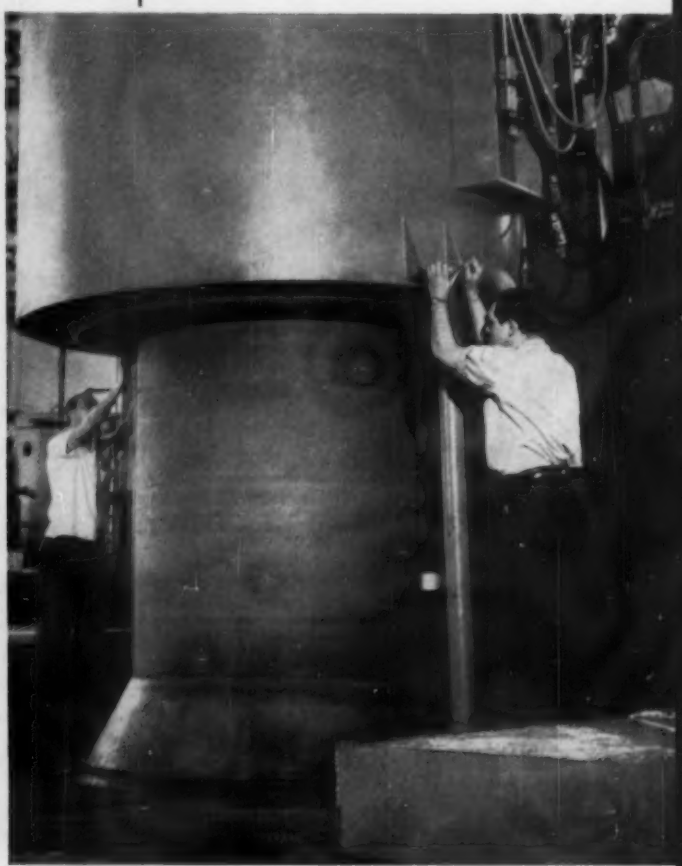
Pratt & Whitney



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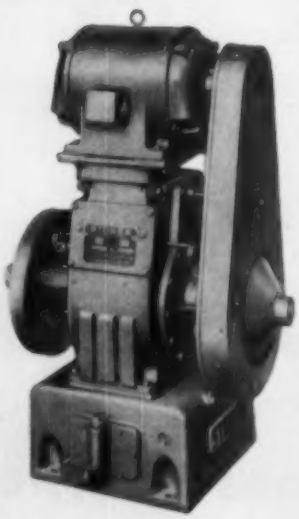

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Aircraft Uses Stokes Furnace to Investigate Vacuum-Brazing of Jet Engine Components

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A logical development of vacuum metallurgy, high-vacuum brazing, presently being investigated by numerous firms throughout the country, promises to produce superior products more economically than brazing methods used heretofore. Tests of vacuum brazed components indicate the greater strength, ductility and uniformity of assemblies produced by this method.

Typical of firms currently carrying on investigations in this field is Pratt & Whitney Aircraft, East Hartford, Conn. The firm is using a Stokes furnace in experimental work on the application of vacuum brazing to the production of jet engine components.

Stokes' furnace design for vacuum brazing is practical . . takes into account the problems of large-scale production. The Stokes dual-chamber design, with a smooth-contour retort completely enclosing the work, permits faster vacuum pumping cycles; provides complete accessibility of the work area and a large, uniform temperature zone.

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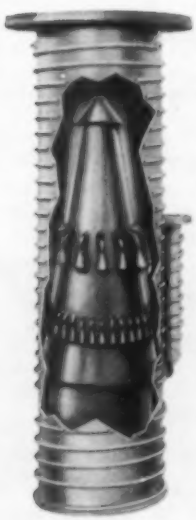
VACUUM EQUIPMENT



STOKES RING-JET DIFFUSION AND BOOSTER PUMPS

The new Stokes Ring-Jet Pumps embody a new concept of the diffusion principle. Size for size, they have pumping speeds of 10% to more than 100% above any other diffusion pump for a given heat input. Ring-Jet Diffusion Pumps are available in sizes of 4, 6, 10, 14 and 16 inches; Booster Pumps in sizes of 4, 6, 10 and 16 inches. Send for information listed.

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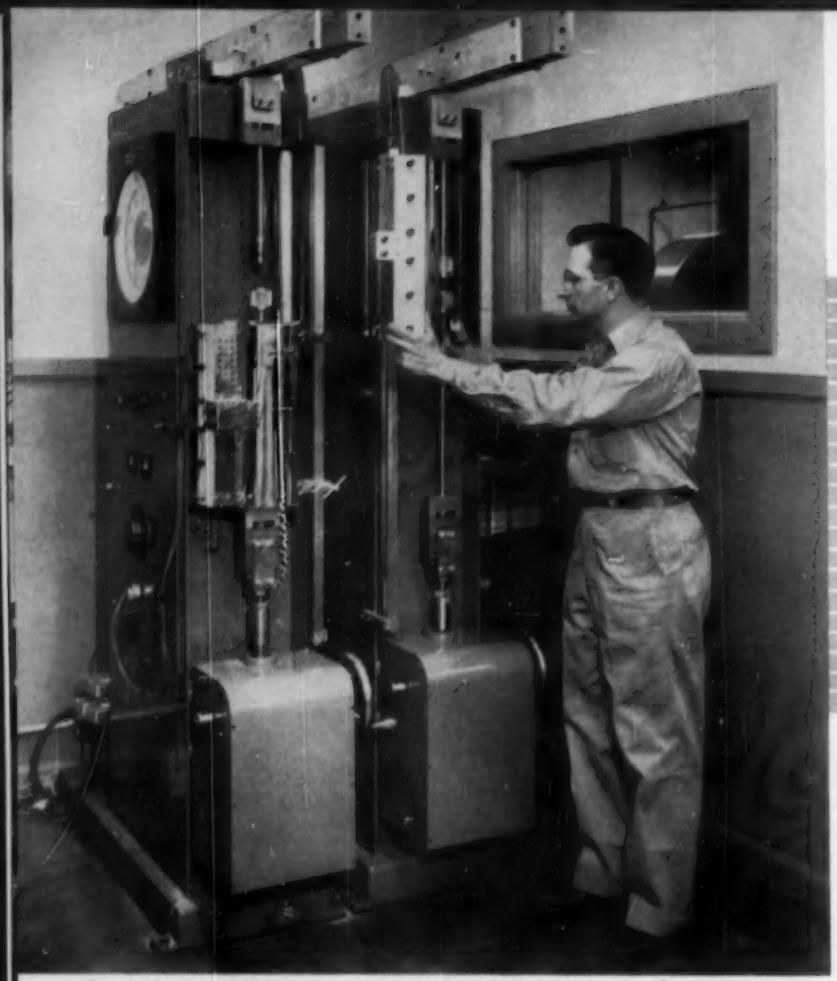

Panel of one machine is mounted left, the other right, to save floor space.

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- Counterweighted beam to permit accurate taring of tools and fixtures
- Automatic beam leveler which takes up strain movement of ductile specimens
- Specimen adapter for threaded-end and shouldered-end specimens
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Riehle Creep Testing Machines can also be furnished stripped down, if specified.

SPECIMEN MISALIGNMENT MINIMIZED — The axial loading fixture utilized on Riehle Creep Testing Machines is ball seated for freedom of motion on both axes.

Members are accurately centered and square, bending moments on the specimen are reduced to a minimum.

Riehle Creep Testing Machines are built with maximum capacities of 12,000 lbs. and 20,000 lbs. Accuracy is guaranteed to be within ½% of load. Full information is given in Bulletin RR-13-54. For your copy, just mail the coupon.

Riehle TESTING MACHINES

A DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

Engineering Digest of New Products . . .

Vacuum Furnace

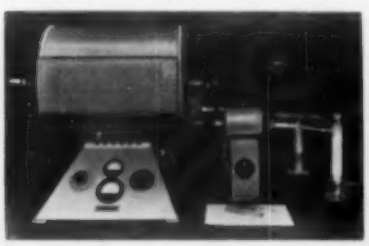
Vacuum Specialties Co. has announced a new vacuum furnace which operates at temperatures up to 2250° C. with good element life and to about 2700° C. with reduced element life. The operating pressure can be maintained at less than 1 micron Hg. The upper tank holds the split-graphite resistance element, in-

sulation and heat shields. The power leads are water cooled and connect to the element in such a way that no hot spots occur. The bottom tank holds a revolving turntable with a six-position indexing mechanism. The work holders sit in recesses around the turntable and are successively raised into the hot element by a pneumatic ram. Thus all six loads can be processed without cooling the element or breaking the vacuum. The furnace is loaded through a port in the top of the bottom tank.

For further information circle No. 1704 on literature request card, page 32-B

Hydrogen Determination

Ledoux & Co. has announced a new instrument for the determination of hydrogen in metals and alloys. The new hydrogen-determinator is based



on the combustion technique and reduces the time per determination to 20 min. in such metals as titanium, molybdenum, tungsten, nickel and cobalt. It determines hydrogen in concentrations as low as 0.003% and as high as those in metal hydrides.

For further information circle No. 1705 on literature request card, page 32-B

Nondestructive Inspection

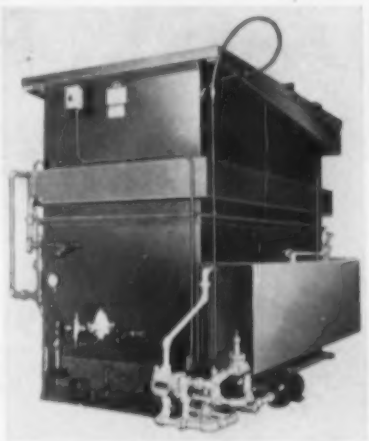
Magnetic Analysis Corp. has announced the development of new electronic testing equipment for the inspection of nonmagnetic stainless steel bars and tubing, seamless and welded. An audio-visual warning system indicates external mechanical defects in bars. In seamless and welded tubing, it indicates mechanical defects both on inside and outside diameters, as well as imperfect welds. Differences in chemical composition and cross-sectional dimensions are likewise detected. A meter and an oscillo-

scope are provided to give more complete information. Testing speed is approximately 200 ft. per min.

For further information circle No. 1706 on literature request card, page 32-B

Vapor Degreaser

Phillips Manufacturing Co. has announced its new series of electric, gas or steam heated heavy duty degreasers to clean parts or assemblies heavily laden with very thick soil, soluble, insoluble, or both. A double sump solves the problem of draining off heavily contaminated vapor degreasing solvent. One of the sumps contains the heating element which



brings the solvent to a boil. The other sump is a repository for the contaminated solvent which runs off from a drain plate above the boiling sump. A removable sludge pan is located in this settling sump.

For further information circle No. 1707 on literature request card, page 32-B

Camera

A new single crystal cylindrical camera, designed to take oscillation and rotation photographs of single crystal specimens on a stationary cylindrical film, has been announced by the North American Philips Co. The technique of rotating the crystal allows the investigator to determine the structure of crystal specimens through analysis of position and

SUN QUENCHING OIL NO. 11 LASTS FOUR TIMES LONGER THAN COSTLY COMPOUNDED OIL

Provides clean bright-quenched parts at lower cost ...keeps tanks and coolers cleaner longer

To get clean, bright-quenched parts, J. W. Rex Company, Lansdale, Pa., one of the foremost heat treaters in the country, had to drain their 1500-gallon quench tank every few weeks. High oil cost and frequent shutdowns for tank and cooler cleaning became too expensive.

A Sun representative made a thorough analysis of this problem. He then suggested a switch to Sun Quenching Oil No. 11—at a price about half that of the costly compounded oil they were using.

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To find out how a Sun Quenching Oil can help *you* heat treat metal at lower cost, phone your local Sun representative or write for Sun's latest Technical Bulletin containing complete information about Sun Quenching Oil No. 11. Address SUN OIL COMPANY, Philadelphia 3, Pa. Dept. MP-12.

J. W. Rex, right, President of J. W. Rex Co. and Sun representative check brightness of an intricate 8620 steel part after quench in Sun Quenching Oil No. 11.

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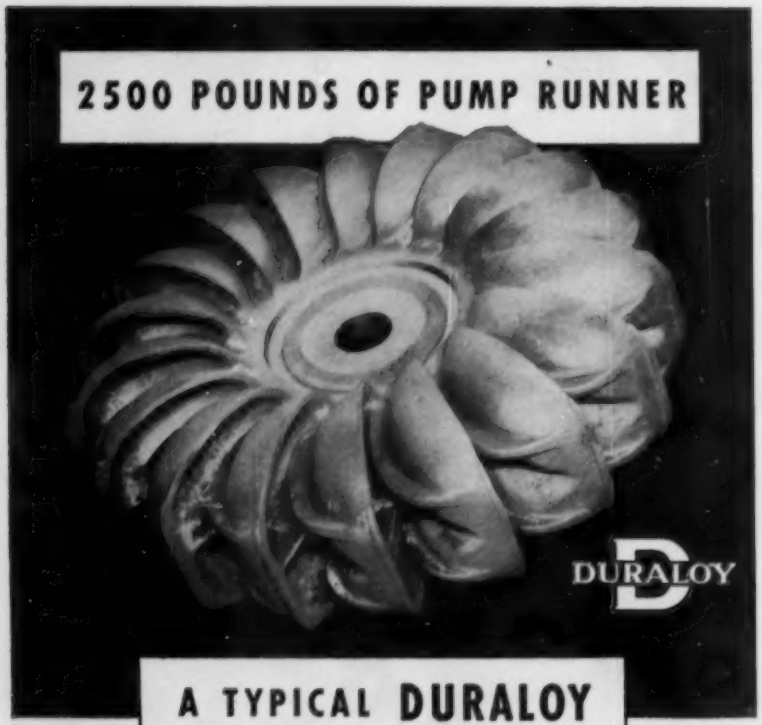
DRAINS OFF PARTS FAST



A TYPICAL **DURALOY** HIGH ALLOY CASTING

This casting is 18-8, destined for use under quite corrosive conditions. It's typical of the work done in our modern foundry for both manufacturers who need high alloy castings for their equipment and for plant operators who need castings to meet a corrosion problem, a high temperature problem or a combination of both, with or without abrasion as a contributing factor.

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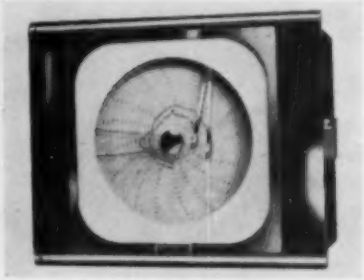
intensity of spots on the film. Horizontal spot patterns, called layer lines, reveal the nature of the lattice unit cell. When various reflections are indexed, it helps in the determination of the corresponding space group. The camera is constructed of cast aluminum with a semi-gloss black finish; the single crystal cylindrical camera is 7 in. high, 6 in. wide and 4 in. deep overall. It consists of six subassemblies—mounting base, drive motor, cable, goniometer head, film cylinder and accessory box.

For further information circle No. 1708 on literature request card, page 32-B

Potentiometer Recorder

A new round-chart electronic dynamaster potentiometer recorder that can make two continuous records at the same time on a 12-in. round chart has been announced by the



Bristol Co. Specific applications where two simultaneous continuous records are helpful include the taking of wet and dry resistance bulb temperatures for humidity measurements, Btu. and temperature differential measurements.

For further information circle No. 1709 on literature request card, page 32-B

Melting Furnaces

A new method for introducing high frequency water-cooled leads to its melting furnaces has been announced by Inductotherm Corp. The leads are introduced through the furnace trunnion, the area of least movement, instead of through the rear of the furnace. The new design obviates the

DECEMBER, 1955
Vol. 2 No. 4

NATIONAL CARBON COMPANY'S

CARBON AND GRAPHITE NEWS

THE TIMKEN STORY . . .

Producing 200 different quality-steel analyses in the electric arc furnace

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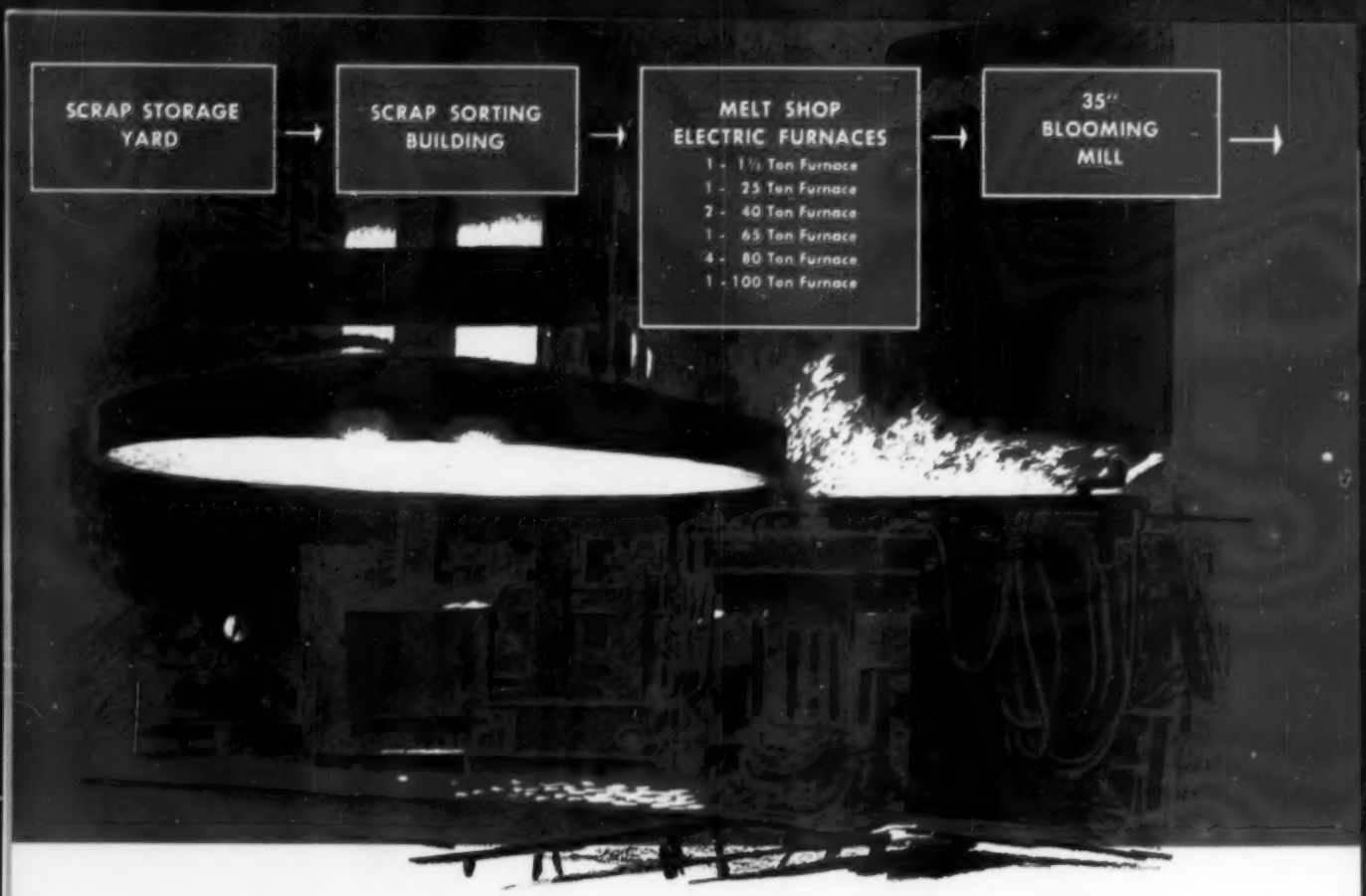

SCRAP STORAGE YARD
SCRAP SORTING BUILDING
MELT SHOP ELECTRIC FURNACES
1 - 1½ Ton Furnace
1 - 25 Ton Furnace
2 - 40 Ton Furnace
1 - 65 Ton Furnace
4 - 80 Ton Furnace
1 - 100 Ton Furnace
35" BLOOMING MILL

PRODUCTION OF QUALITY STEELS IN THE ELECTRIC FURNACE

By Harry F. Walther, *Superintendent, Melting**

To assure a steady supply of consistently high quality steel, The Timken Roller Bearing Company, early in its corporate career, decided to make its own steel.

The first electric arc furnace installed at The Timken Roller Bearing Company's steel plant went into operation in August, 1916. The first installations were small and rather crude, but from that time on the company's capacity has steadily grown to keep pace with the demand for high quality steels. This growth has occurred in number of furnaces, in size of individual furnaces, and in such technological aspects of furnace operation as instrumentation, electrical and mechanical auxiliaries and in metallurgical and process control.

Later, it was planned to install three open hearth furnaces. The first heat was tapped in March, 1927. However, for certain economic and technical reasons, it was decided to replace these furnaces with new, modern, top-charge arc furnaces of the latest design. Subsequently, the last open hearth heat was tapped on November 29, 1952, and by January 13, 1953, the Melting Department was completely converted to an all-electric shop, with an annual capacity of 650,000 tons of high quality alloy steels.

Why did we become an electric melt shop? Consideration of some of the problems involved in large-scale manufacture of bearing steels and other quality steels may help explain the reason for this decision to the reader not already familiar with the fundamental differences between a "job" shop operation on a wide variety of analyses and that of the integrated steel mill, producing great volumes of carbon steels within a relatively narrow range of grades.

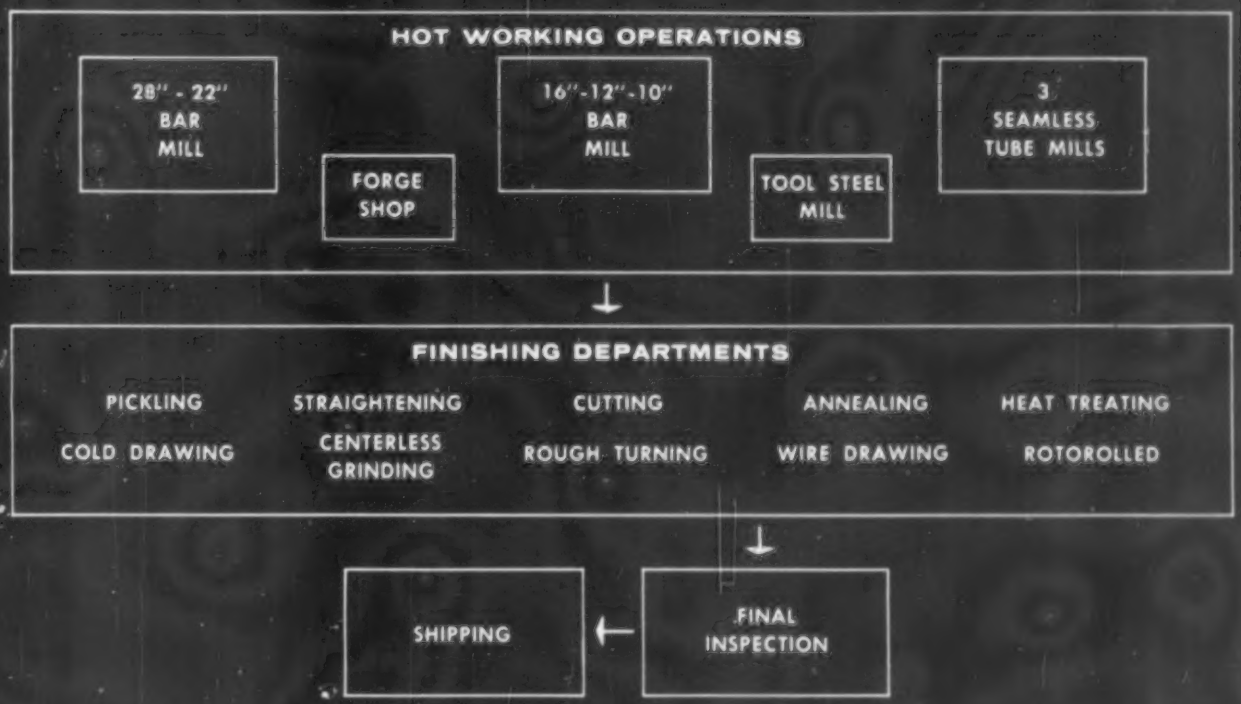
QUALITY IS ECONOMY

The Timken Company produces some 200 different steel analyses, all subject to more rigorous quality standards than those usually imposed on the more common, low-carbon steels. It is evident that, in a shop where one 25-ton heat may represent as much as $17,000, any production economy established at the risk of quality is a false one. The much closer metallurgical control afforded by the electric arc furnace, with its assurance of high, uniform quality in every heat, is possibly the greatest single source of true economy to the alloy-steel producer.

ALLOY STEELS—Special and Varied

The Timken Company's steels are varied both as to their chemistry and the uses to which they are put. Frequently, as many as eight different analyses are found in the furnaces at one time; quantities range from as little as three thousand pounds of some highly specialized or experimental analysis up to more than one-hundred-ton heats of the more widely used types. Obviously, a much greater flexibility to meet such requirements exists in the electric furnace shop, equipped with 10 units, ranging from 1½ to 100 tons, than could be obtained with any other practical combination of alloy steel-making equipment.

*The Timken Roller Bearing Company



MULTIPLICITY OF USES

Timken steel in the form of bars and tubing is used by virtually every major industry. This fact further complicates the problem of inventory. Demand fluctuates, both in quantity and in grades of steel required. Specifications of individual customers are constantly changing. Scheduling is made difficult by the varying delivery requirements of a diversified market.

Products for this broad market include *rock bit steel* (special high carbon steel held to extremely narrow limits of controlled hardenability); *aircraft* and *automotive steels* (including alloys for jet engines); *tool steels* (including graphitic grades); and, of course, *bearing steels*, which the Timken Company supplies to 24 other bearing manufacturers, in addition to its own requirement. The great diversification of this market, with its attendant problems of inventory, places a high premium on the flexibility of the electric furnace – the speed with which it can be started up or shut down, ease of rebuilding and preparation for melting, its relatively short heat cycle and high yield in tons-per-hour.

While, in general, the above considerations do not shed much light on the relative merits of electric furnace vs. other methods of steel-making, they *do* explain why The Timken Roller Bearing Company's Steel and Tube Division operates an all-electric melt shop. Now, just what is involved, production-wise, in quality steel-making by the electric arc furnace process?

SCHEDULING

Our first consideration in scheduling a heat is the customer's final application of the steel. Detailed records are kept of practices used in previous melting of all analyses, from which it is possible to determine the best practice for each current job.

The Production Department initiates the schedule, with all information relating to type, quantity, size and tolerances required by the order.

In the Metallurgical Department, complete melting procedure is outlined from melt-down to tap and on through the other mill operations. Melt shop supervisor and melter, working from these data, are able consistently to deliver a metallurgically-controlled product from raw material to ingot.

CHARGE

Availability and proper identification of raw materials is of particular importance to the large, alloy steel shop. Slag-making materials, alloying ingredients and scrap must be of the highest, *uniform* quality possible to speed selection of the charge and to assist in standardizing slag-making procedure. There are some 35 classifications in our own shop and all incoming raw materials are carefully checked against strict specifications.

If the analysis to be made involves such non-oxidizing elements as nickel and molybdenum, a high percentage of specification of these elements is charged, either as scrap or in other available forms. Oxidizable elements like manganese and chromium are generally held to a minimum except for the obvious exception of a high percentage of stainless scrap charge. In the latter instance, we employ a special practice for the removal of carbon, using oxygen, followed by "turning" of the slag for practical recovery of the oxidized elements.

Undesirable elements such as phosphorus and sulphur are kept below specification in the charge or low enough that they can be easily reduced to the required minimum during normal processing. In the large job shop, heat time and correct analysis are highly dependent on the availability and proper classification of all charging elements.

(continued next page)

OXIDIZING PERIOD

As in the production of most quality steels, the Timken Company uses a two-slag, basic practice: an oxidizing slag followed by a reducing slag. During the oxidizing period, such elements as carbon, phosphorus and some sulphur are removed from the bath by oxidation and slag-metal reactions. This is accomplished by adding lime to the slag and introducing oxygen to the bath as ore, scale, sinter or gas. The oxidizing period normally is concluded when carbon has been lowered to the specified level. At the end of this period, the slag attains a weight of 2 to 4 per cent of the metal bath, a weight-per-cent ratio of lime to silica in the range of 2.0 to 2.8, and a total FeO content of from 5 to 30 per cent, depending, generally, upon the carbon level in the bath and the basicity of the slag.

The literature is rich in data covering the effects of oxidizing slags on such residuals and additives as carbon, manganese, silicon, chromium, phosphorus and sulphur in the molten bath. More and more, metallurgy is extending its investigations beyond the physics of metals and into the realm of their complex chemistry in the search for a clearer understanding of slag-metal and metal-gas reactions.

REDUCING PERIOD

Following slag-off, and such additions as are necessary at that time, a reducing slag is added for the purpose of further refinement. Slag volume during this period is usually 2 to 4 per cent by weight of the bath. About 20 minutes are required for the slag to "shape up". After the reducing slag is added, and throughout the refining period, judicial additions of a reducing agent such as coke and silicon are made to keep the slag "deoxidized". Silicon may be substituted for coke in melts where carbon pickup is a hazard.

Refining-slag make-up varies widely, but in normal carbide slag practice it will have a lime-to-silica ratio in the range of 2.2 to 4.5 per cent by weight, a calcium carbide content of about 0.5 to 4.5 per cent, FeO content under 2 per cent, and a CaF_2 content in the range of 2 to 15 per cent. Here, again, the literature includes a wealth of findings on many aspects of refining-slag reactions.

The refining period ends with addition of such alloying elements as are shown by test to be needed to meet specifications. Following the refining period, final deoxidation is effected by additions of aluminum or other suitable materials, if required, and the heat is ready to be tapped.

POURING THE INGOT

During the pouring process, as in every previous stage of production, precaution is taken to prevent contamination of the metal. All molds are vacuum cleaned in the pit and mold plugs are made of a special, all-carbon mix instead of the more common clay, in order that non-metallic inclusions may not be introduced into the ingot. We have found that good housekeeping contributes to the good work-habits so necessary to uniformly high quality.

All ingots have ceramic hot-tops and are cast at a rate calculated to maintain desired surface and internal quality. The pouring nozzle is a ceramic refractory which is tar-impregnated to reduce bore erosion and thus makes possible a sustained, uniform rate of pour.

PROCESS CONTROL

Repeated mention has been made of the necessity for close quality control in the production of alloy steels and of the features of electric furnace operation which make this control possible. However, these features are only the instruments by which high quality *can* be achieved and maintained. In order to employ them properly, an accurate knowledge of what is in the furnace and of what is happening to the metal in the way of temperature, slag chemistry and chemical composition of the bath is required at every stage of production.

During the oxidizing period, basicity of the slag is very important. Measurement of slag basicity is obtained by the "pancake" method of visual inspection. Another vital factor in alloy steel production is bath temperature. The Timken Company was among the first to use immersion thermocouples for accurate bath-temperature determinations and it is in good part due to our success with this method that it has become virtually standard in the industry. Temperatures are directly related to power input and a detailed graphic record of the latter is kept as an important item of process control. In addition, a graphic record is kept of all immersion thermocouple readings taken during the heat.

As soon as the furnace charge has been melted down, a sample is taken and immediately analyzed for type and percentage of alloys present. With this "melt-down" test report

before him, the melter determines the alloys that must be added to adjust the steel to specifications. Following slag-off and during the refining period, additional metal samples and temperature readings are taken for final adjustment of the melt.

When the metal is teemed into ingots, final samples are taken to determine the "ladle analysis". Because it includes residual aluminum, the ladle analysis yields, among other valuable data, a quick and accurate indication of inherent grain size which is very important information for the process metallurgist. This test and those made on samples from the subsequent blooms comprise the official chemical analysis of the heat which is sent to 30 individuals or departments in the company.

The Timken Company employs both conventional wet chemical analysis and spectrographic methods – the latest being a direct-reading Spectrometer which reduces the time required for a complete analysis from about 45 minutes to six minutes. The value to the melter of such rapid determinations is incalculable. Heats need no longer be held for long periods in the furnace pending reports. The melter receives his data while the heat is still in approximately the same condition as when the test sample was taken.

Melt-down and prelim tests, except for carbon, phosphorus and sulphur, are run on the Spectrometer only. Similar tests on the ladle are double-checked by wet chemical methods. A pneumatic tube system carries the test samples from melt floor to laboratory. Results are telautographed to the melter who enjoys instantaneous, two-way communication with chemical and spectrographic labs. Other direct-line, two-way communications include those from cranes to melt floor, floor to pit, pit to cranes, and stock-house connections with both cranes and melt floor. As a part of its records system, the Timken Company keeps a heat-log for every melt, showing variations in compositions of the metal and the slag from tap to tap.

IMPROVED TECHNOLOGY

Because it is the newest of the established steel-making techniques and because it was early identified with quality steel-making, the electric arc furnace has undergone the greatest variety and degree of refinement of any steel producing method. Furnace capacities have increased; transformer improvements have exceeded the greatest expectations of early equipment manufacturers; switch gear and power controls have reached a high state of efficiency. The electrode industry has produced electrodes of sizes and quality not thought possible fifteen years ago. Power companies have provided a stable source of energy which probably is the important fundamental requirement. However, no single phase of technological improvement by itself can lay claim to the present successful operation of our modern furnaces. The proper functioning of all component parts is an absolute necessity.

Other engineering developments have aided the melter in controlling the molten bath and in increasing production. Among these are the direct-reading Spectrometer, immersion thermocouple, carbometer, telautograph and various graphic meter recorders. Induction stirring has also provided a means for more accurate chemistry and temperature control. Much of the guesswork has been removed from melting by making use of these scientific devices. The use of oxygen in the bath has made it possible to recover vast amounts of chromium and to produce extra low carbon steels of stainless types with a minimum of difficulty.

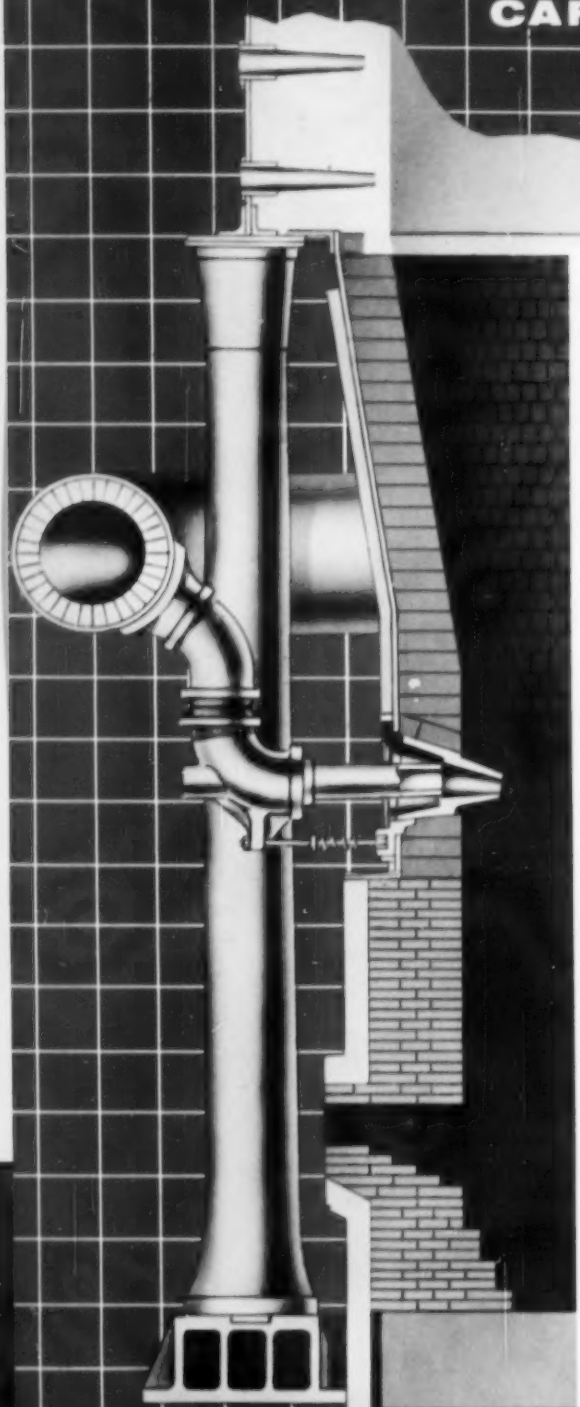
Improved refractories have likewise played a most important part in advancing operating techniques. Fully rammed bottoms of various excellent mixes have eliminated much of the drudgery and plain guesswork from hearth maintenance. Basic brick sidewalls, particularly metal encased, have provided a distinct advantage to operators.

We cannot overlook the part metallurgists have played in improving metal quality. By applying the results of statistical evidence and making use of a better knowledge of slag-metal-temperature-gas relationships, it is possible to improve melting techniques to meet almost any rigid requirement desired by the customer.

Alloy manufacturers are now supplying materials which make possible the production of complex steels which, until comparatively recent times, were economically impossible.

We can only speculate as to what the future may bring. Certainly, as the demand grows for steels to resist higher and higher temperatures and to provide increasingly greater strength and wear and chemical-resistance, the electric furnace will be required to shoulder an increasingly greater share of the steel-making burden. The history of its development indicates that it will continue to improve in its ability to meet these requirements.

A report on NATIONAL CARBON BLAST FURNACE LININGS



From the time of its introduction in this country as a blast furnace refractory, "National" carbon has continually gained in acceptance because of its superior service performance. Research into design and construction of carbon blast furnace linings and thorough analysis of their service advantages are now accomplished facts. Summarized here are some of the data currently available from both operating practice and research.

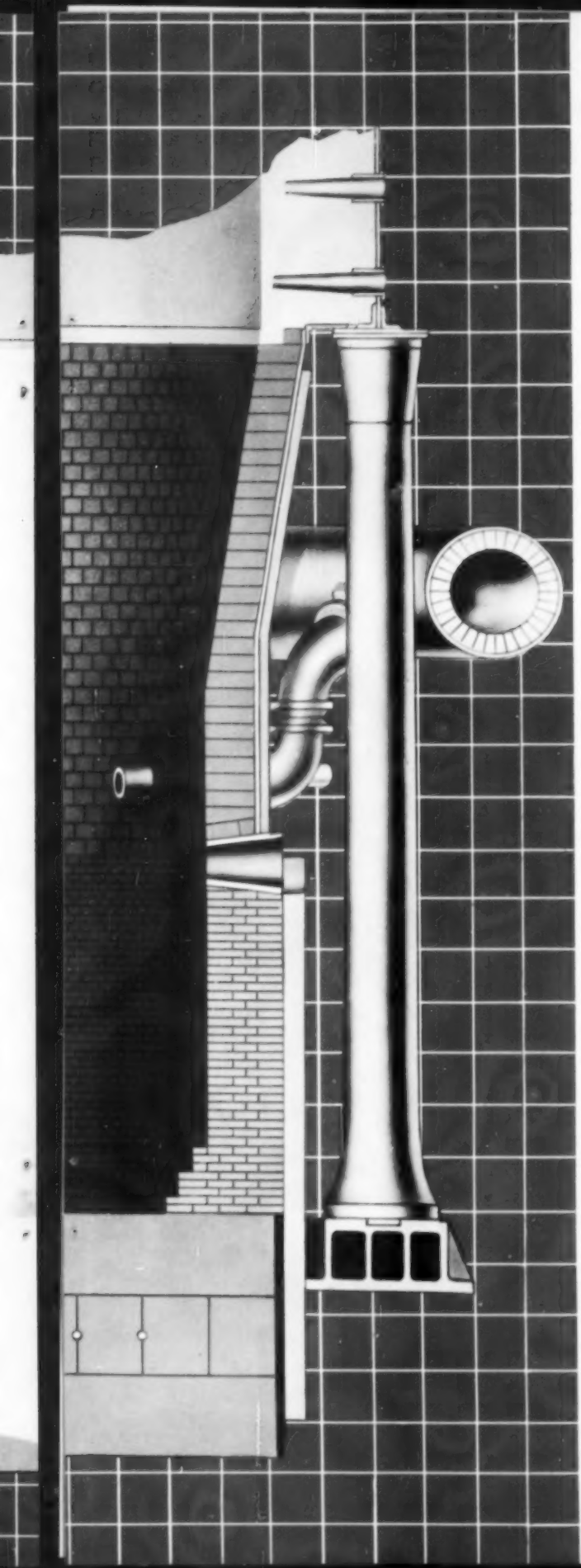
HEARTH WALL

Inconsistent hearth break-out records for materials other than carbon were a major reason for carbon's rapid acceptance. Performance of carbon in some 145 blast furnace hearths in North and South America provides strong evidence that hearth lining life can be *safely* extended by two or more times the life expectancy previously regarded as standard for other materials. Blast furnace break-outs were sharply reduced with "National" carbon linings of the original design, and features of the present "National" carbon design are an even greater improvement. Examination of carbon hearth walls between campaigns reveals very little wear and uniform thickness, in contrast to dangerous thinning of other materials. More than twenty "National" carbon linings have been removed to make a thorough analysis of their condition. The marked decrease in wall-thinning together with the absence of breakouts in these hearths have encouraged blast furnace management to identify the carbon hearth with longer, safer life. Cumulative experience now indicates that one "National" carbon hearth lining can remain in service during the life of at least two stack linings – resulting in appreciable savings of time and money.

Full-wall installations of "National" carbon brick date back to 1945, with continuous campaigns of up to 2¾ million tons. Such outstanding service has been repeated many times in part-wall patches of carbon brick work.

This accumulation of service experience and of examination and research data has firmly established the soundness of the present design, favored by the industry and recommended by National Carbon Company.

In this present design, the hearth wall is at least 22½ inches thick, constructed of carbon brick installed directly against external cooling. The quality of hearth wall linings is further assured by using "National" carbon brick of machined tolerances for desired uniformity and MC-2, a superior "National" carbon cement, extremely workable for highest quality bricklaying and high bonding strength.



The hearth shell should be air-tight and gas-tight, with the cooling restricted to the outside of the wall.

IRON NOTCH

The iron notch is a critical area of the hearth wall lining. "National" carbon in large blocks or brick shapes has proven its superiority in this location as patches in linings of other materials and in full carbon hearth linings.

Frequently, it is desirable during a stack reline to remove the carbon iron notch area for examination and replacement with carbon. This work is done at a minimum of cost and without loss of time while the stack-work above the "permanent" scaffold is in progress. The dimensional stability and infusibility of lining members made of carbon make possible a clean removal of this wall segment at the desired joints and the replacement of materials.

HEARTH BOTTOM

Linings for hearth bottoms, as for hearth sidewalls, are chosen to retain molten iron safely for long campaigns.

Salamander size has been the most common problem. Sometimes this condition is considered detrimental to furnace operation, but a more serious problem is removal of the salamander at the end of the campaign. Tapping the molten metal to the outside is less expensive than removal of solid metal, but tapping is not always possible nor is it always accomplished without accident. In any event, salamander removal is a serious undertaking, the problems and cost of which are worthy of being minimized through the use of "National" carbon bottoms.

For many years, blast furnaces have been built with very thick bottoms to accommodate salamander formation. Thus, breakouts are less frequent through bottoms than through sidewalls. However, when the bottom does fail, the damage usually is more extensive.

The heat conductivity of "National" carbon bottom blocks is sufficiently high to provide an adequate route for the central heat to travel horizontally outward to the vertical cooling when the carbon bottom is of proper thickness. A carbon bottom thickness of approximately one-quarter of the outer diameter of the lining will retain the "freeze-line" well within the carbon.

It is interesting to note that more attention is being given to the design of blast furnaces to provide cooling under the carbon hearth. Available heat distribution data indicate that bottom cooling is practical. Five such bottom-cooled carbon hearths are operating in Sweden, Austria and France.

Such bottoms can be supported on structural steel. Raising the hearth off the ground, as has been suggested, would provide a more suitable means of obtaining a gas-tight, air-tight outer shell, eliminating ground moisture problems.

The recommended "National" carbon blast furnace hearth lining now includes a carbon hearth bottom approximately 7 feet thick constructed of large blocks. All surfaces are machined for face-to-face contact. Half-round keyways are machined in each vertical face for continuous graphite key-rods to provide a "locked-in" hearth construction.

BOSH WALL

A bosh lining should withstand the high temperature and erosive action of the blast furnace (solid-to-fluid state) and particle-laden, high-velocity gases. It should also allow uniformly free movement of furnace burden for the most efficient gas-to-solids contact, a fact not always considered.

(concluded next page)

The accepted practice for years has been to imbed water-cooled copper plates in a systematic pattern throughout the bosh. The linings thus "stabilized" nevertheless cut back rapidly, exposing the nose of each plate, which protrudes inward, without protection. This condition establishes cooling "spots" which tend to chill the slag and other burden in irregular, changing patterns during operation. Downward stock movement and upward gas flow are thus hindered and "channeling" results, starting at the bosh wall. This condition is undesirable from the standpoint of gas-to-solids contact and creates wide temperature fluctuations in the stack wall. These factors are detrimental to the lining and cause "scab" formations which reduce working volume and are otherwise undesirable.

The use of imbedded cooling plates in a carbon bosh wall is unnecessary and, from the standpoint of installation and maintenance, *highly undesirable*. Carbon bosh lining blocks of special, small shapes are laid directly against a solid, welded steel jacket since cooling of the outer shell is adequate.

Construction cost analyses made by a number of organizations confirm the fact that a carbon bosh can be installed for less total cost than the internally cooled type. The greatest savings result from the elimination of cooler plates and the necessary labor time required for the tedious fitting around these plates.

Carbon is a material to which the burden will not adhere, and it maintains a smooth surface. Furnace operation is improved by the consistently free movement of the furnace burden through the bosh area.

Inside furnace diameters often have been enlarged by lining with carbon up to the mantle. Thinner walls of carbon are possible within the same hearth and under the existing stack shell. Rated furnace capacity can be increased up to 20% in this way, at minimum cost.

CONCLUSION

Safety, smooth operation and long, trouble-free service-life are now firmly established features of "National" carbon linings for blast furnaces. Furthermore, a properly designed carbon lining offers the advantage of increased furnace capacity at minimum cost. Because of its pioneer work and continuing research and development in this field, National Carbon Company can be of invaluable assistance to blast furnace users in the development of cost analyses and in recommended designs for the proper application of this superior refractory material.

National Carbon Company recommends:

HEARTH WALL

Blast furnace hearthwalls made of "National" carbon brick of machined tolerances, using a minimum wall thickness of 22½ inches, joined with "National" MC-2 carbon cement. The hearth shell should be air tight and gas tight, with adequate cooling restricted to the outside of the wall.

IRON NOTCH

Iron notch constructed of carbon brick shapes or especially machined blocks of carbon.

HEARTH BOTTOM

Hearth bottom approximately 7 feet thick, constructed of large "National" carbon blocks, with all surfaces machined for face-to-face contact, and half-round keyways in each vertical face for continuous graphite key rods to provide a "locked-in" hearth construction.

BOSH WALL

Bosh walls built of special small shapes of "National" carbon, laid directly against a solid welded steel plate jacket. Internal cooling plates are eliminated since external wall cooling is adequate.

Previous issues of CARBON AND GRAPHITE NEWS are still available.
Write National Carbon Company, 30 East 42nd Street, New York 17, New York, giving name, title and company address.

The term "National" is a registered trade-mark of Union Carbide and Carbon Corporation

NATIONAL CARBON COMPANY
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, New York
In Canada: Union Carbide Canada Limited, Toronto

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Diamond in the rough

This 42,000 pound Finkl FX die nearing completion at the Ladish Co., Cudahy, Wisconsin, will be utilized by that firm in drop forging 1681 pound close tolerance aircraft propeller blades. FX is but one of many Finkl steels available for forging operations, all of which are quality controlled with "built-in" characteristics required for precision production. For the proper die steels to fit your needs, ask your local Finkl representative or write for the Finkl catalog.

When you next consider hot work tooling, die blocks, or forgings, call on Finkl for "impressions that last."

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Three NEW Refractory Products For Reaction Motors

IN THIS "high temperature age," when industry is asking for materials with ever higher melting points, the requirements of reaction motors are extremely demanding.

Depending upon extreme temperature differentials in converting heat into useful work, the power plants for jet propulsion present unique time-vs.-temperature problems. To meet these problems, component materials must be able to withstand not only very high temperatures but also other factors such as thermal shock, erosion, corrosion and oxidation.

Aware of these requirements, Norton Company has for years been engaged in a program of experimentation, development and testing of various materials. A number of these have proved highly satisfactory for reaction motor and similar applications; in particular, the three described below.

ROKIDE* "A" Aluminum Oxide Coating

A hard, adherent, refractory oxide coating, pure white in color and containing about 98.6% Al_2O_3. It has been successfully applied on ceramics, glass, and certain plastics but particularly on metals in thicknesses of .005" to .050", and greater in special cases. This crystalline oxide coating protects the base material under high temperatures and erosion conditions, and its alumina, being harder than the hardest steel, provides strong resistance to abrasion. ROKIDE "A" coating is thermally and electrically insulating and is slightly permeable. This coating and coating process are covered by U. S. Pat. #2,707,691.

ROKIDE "C" Silicon Carbide Coating

This coating was developed to improve graphite components for high temperature use. It consists of a protective layer of pure CRYSTOLON® silicon carbide, of dark gray or gray-green color, formed at high temperature on the graphite, to protect it and increase its resistance to erosion and oxidation. The coating varies between .002" and .030" but is usually around .010". It reacts integrally with, and becomes a part of, the graphite surface. A considerable part of the coating, therefore, is chemically derived from the graphite itself. ROKIDE "C" coating has excellent thermal shock resistance and extreme resistance to abrasion. It is slightly permeable. This coating process is covered by U. S. Pat. #2,677,627.

CRYSTOLON® "N" Silicon Carbide Products

These are monolithic bodies, kiln-fired at high temperature and molded to close dimensions in a wide variety of shapes and sizes. They have greater resistance to mechanical and thermal shock than most ceramics and, compared to other commercial refractory products, are very strong. CRYSTOLON "N" material is dense and extremely refractory. Products made of it have been used successfully at estimated temperatures as high as 5000°F for varying periods of time.

Applications

Typical applications for which these products have shown exceptional promise:

Rockets: nozzles, motor tube linings, thermal barriers.

Guided Missiles: vanes, skin protection, motor components.

Ram Jets: tail pipe lining.

Gas Turbines: inner combustion chamber lining, cross fire tube lining, flap nozzle coating, housing and shroud ring insulation.

Miscellaneous: burner parts protection, electrical insulation, thermocouple tube protection.

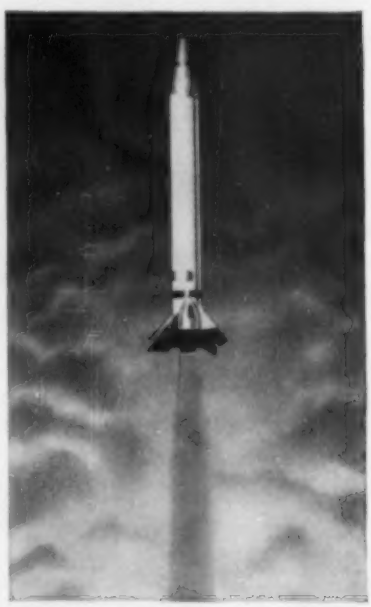
Licensing Policy

A license for the use of the ROKIDE "A" aluminum oxide coating process can be obtained from Norton Company.

Other Norton Products

of interest to designers and builders of reaction motors include refractory ceramic materials of commercial type, including fused stabilized zirconia, various CRYSTOLON products, MAGNORITE® fused magnesium oxide products and ALUNDUM® fused aluminum oxide products. Norton also makes a number of refractory carbides, borides and nitrides. These high-melting materials, which have varied applications in many fields, are also the basic ingredients of the famous Norton Refractory Rx's — refractories *engineered and prescribed* for the widest range of uses.

For further information on Norton products for reaction motors — or for other applications — write, mentioning your requirements, to NORTON COMPANY, 333 New Bond Street, Worcester 6, Mass.



In Rockets, Jet Planes and Guided Missiles, Norton products for reaction motors — ROKIDE "A" Aluminum Oxide Coating, ROKIDE "C" Silicon Carbide Coating and CRYSTOLON "N" Silicon Carbide Monolithic Bodies — are used for many applications.

NORTON

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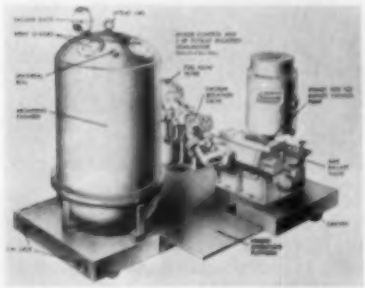
necessity for longer leads and the deep pits at the rear of the furnace. Furnaces incorporating this new design have been built for air and vacuum melting in capacities of 30 to 2000 lb.

For further information circle No. 1710 on literature request card, page 32-B

Vacuum Degassing

Kinney Mfg. Div. has announced a new mobile vacuum degasser for ridding metals of entrapped gasses and other impurities. The new unit is mounted on wheels, is 6 ft. square and 5 ft. high and consists of a mechanical vacuum pump and gear-motor, filter and degassing chamber. Melt is loaded in degassing chamber and

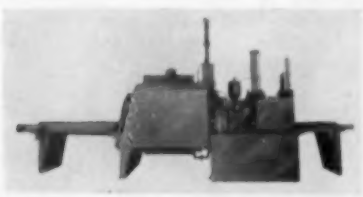


pump begins operating, dropping chamber pressure to about 0.750 mm. The vacuum causes the molten metal to boil, liberating gas trapped in the metal. The boiling action subsides gradually during the process and the pressure drops also as the melt becomes passive.

For further information circle No. 1711 on literature request card, page 32-B

Heat Treating Furnace

Ipsen Industries has announced a new line of heat treating furnaces in which the loading, heating and quenching capacity have been in-

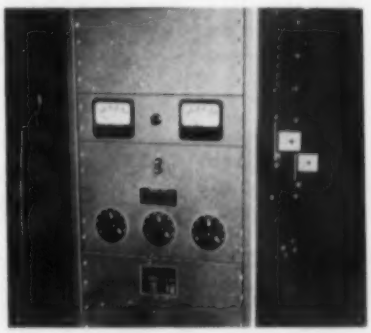


creased 50%. New style ceramic tubes and redesigned elements and burners are capable of generating higher operating temperatures quickly and economically. Atmosphere circulation has been stepped up and maintenance costs reduced with a new fan design. A completely redesigned quench tank arrangement has increased the circulation of high and low oil as much as 300%. The quench tank itself is 50% larger and located as far from the heating zone as possible for greatest safety. Partlow instrument guards against overtemperatures of the quench oil.

For further information circle No. 1712 on literature request card, page 32-B

Germanium Rectifiers

The Walter Div. of Norma-Hoffmann Bearings Corp. has announced a new line of germanium rectifiers. They are available in several models



in various amperes, d-c. output. Because there are fewer moving parts, maintenance costs are practically nil. Germanium rectifiers require few components and have high efficiency so they can be small in size and can be installed in a small floor area.

For further information circle No. 1713 on literature request card, page 32-B

Coating Aluminum

A new cold chemical finisher for aluminum coating has been announced by the Birchwood Chemical Co. The formula gives a soft or high gloss finish immediately upon application. Only 1 min. is required for drying. It can be dipped, sprayed or applied with a rag or brush. There is no surface spotting or density variation and if left unrubbed a dull gloss finish is obtained. If rubbed, a high-gloss finish will result. Principal uses are in retouching and for the fabrication of small parts.

For further information circle No. 1714 on literature request card, page 32-B

Slotting Machine

A new screw head slotter capable of delivering up to 51,840 slotted blanks per hour has been announced by the Waterbury Farrel Foundry & Machine Co. The new machine slots standard or special headed, ferrous or nonferrous blanks, No. 6 to ¼ in. diameter up to 2½ in. long, at variable speeds from 60 to 864 per min. One dial, furnished as standard equipment, feeds this range of blank diameters. To handle other diameters the machine can be equipped with special

dials. The only tooling required is a saw and burr-remover blades made from spring steel.

For further information circle No. 1715 on literature request card, page 32-B

Potentiometer

A miniature strip chart recording potentiometer, weighing less than 25 lb., with standard charts and ranges for copper constantan, iron constantan and chromel alumel thermocouples and internal cold junction

compensation has been announced by Westronics, Inc. This recorder, of the null balance potentiometer type, records on a 5-in. strip chart, with a pen speed of 1 sec. full scale and an accuracy of better than 0.5%. A variety of chart speeds are available, with 3-speed chart drive optional.

For further information circle No. 1716 on literature request card, page 32-B

Vacuum Gage

A new one to four-station vacuum gage which gives continuous pressure readings from 100 mm. to 1 micron Hg has been announced by Consolidated Vacuum Corp. It is a self-balancing, direct-reading, hot-wire type

vacuum gage. Outstanding feature of the instrument is its automatic switching from the millimeter range to the micron range. Other major features include wide measuring range, ability to actuate an external relay circuit, and connection for four gage tubes.

For further information circle No. 1717 on literature request card, page 32-B

Steel-Plastic Material

Chemical Development Corp. has announced a plastic steel consisting of 80% steel and 20% plastic, now being used for making tools, drill jigs, fixtures for holding parts during machining, buffing and assembly, and other purposes. It is as easy to handle as modeling clay. Two hours after the addition of a special hardening agent, the mixture of steel and plastic becomes a rigid, steel-like mass. No heat or pressure is required. Once hard, it can be sawed, threaded, drilled or ground on regular metalworking equipment. Devcon is available as a putty or as a viscous liquid that can be poured.

For further information circle No. 1718 on literature request card, page 32-B

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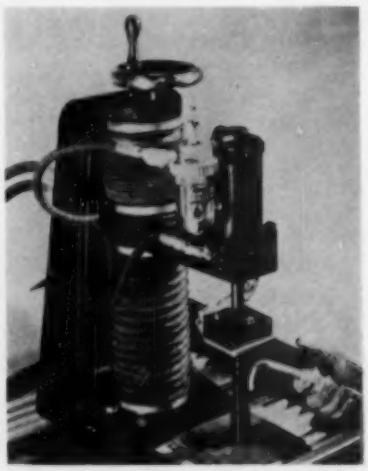
Inspection

Magnaflux Corp. has announced new auxiliary equipment to increase inspection rates without obsoleting existing units. The X-1584 vertical contact adapter is really a special jig which fits any standard horizontal

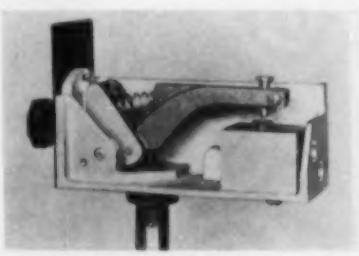


unit. Almost no installation is required, and once installed it can be connected or disconnected in 2 to 5 min. It comes with quick disconnect air hoses for the necessary pneumatic connections. Cables and attachments for magnetizing current are also provided. The adapter clamps on the rails with a lockshoe and draws power and air directly from the Magnaflux unit. The adjustable contact heads will handle parts 12 in. long and up to 10 in. in diameter.

For further information circle No. 1719 on literature request card, page 32-B

Temperature Control

A new controller for use where temperature is to be controlled by varying the flow of gas, steam, or other medium with an air-operated valve or motor has been announced by Burling Instrument Co. It may be



used in any pneumatic system up to 50 psi. and will reduce the output or branch line pressure as temperature increases. Since it operates by the differential expansion of solids and uses no liquid or vapor fill, it is available for temperatures up to 1800°F.

Control is obtained by the difference in expansion of two concentric tubes actuating a pilot valve through a lever.

For further information circle No. 1720 on literature request card, page 32-B

Low-Frequency Transducers

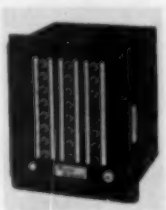
New low-frequency, flat-type transducers have been announced by Circo Equipment Co. for ultrasonic metal degreasing equipment. Low frequency ultrasonic waves, generated by barium titanate transducers of new de-

sign, curve around corners and sharp angles, penetrate more easily into recesses and capillaries to remove all dirt, oil, grease, chips and lapping compound from the article to be cleaned. The flat shape of the transducers permits them to be joined to any length or width.

For further information circle No. 1721 on literature request card, page 32-B

Switches for Thermocouples

For circuits where a large number of thermocouples or resistance bulbs must be frequently checked or switched from one instrument to another, or where one instrument must be switched to many measuring points, Thermo Electric Co. has announced cabinet-type selector switches. These switch assemblies can be used with all types of pyrometers, millivoltmeter or potentiometer and resistance thermometer. Switches are key-type, double-pole three-position action. Cross-bar contacts are of palladium, contact springs are of tempered nickel silver.



For further information circle No. 1722 on literature request card, page 32-B

Gas Generator

An endothermic gas generator to provide atmosphere for neutral hardening or carburizing of steels has been announced by California Alloy Products Co. The retort is gas heated by atmospheric burners. Temperature is controlled at 1850° F. by a pyrometer operating a solenoid valve. The gas air mixture is pumped through the retort by a variable speed drive. A dew point indicator is located on the control panel. One model produces up to 1000 cu ft of gas per hour. The analysis, operating on natural gas, is nominally 40% hydrogen, 40% nitrogen, and 20% carbon monoxide.

For further information circle No. 1723 on literature request card, page 32-B

Deburring

Lord Chemical Corp. has announced a new fine-grain abrasive compound for fast deburring and stock removal. It produces a smooth finish and good color. It is used with abrasive chips, generally at low water level, and is also suited to the self-tumbling of small parts. This compound should not be used where runs longer than 6 hr. are necessary.

For further information circle No. 1724 on literature request card, page 32-B

Regulator

Hauck Mfg. Co. has announced its new air-oil ratio regulator for controlling oil burners by the varying of pressures. It is designed to deliver the proper oil pressure which will correspond to the air pressure going through the burners. It functions over a wide range of air pressures and is not affected by the normal amount of

the new Cooley BATCH TYPE controlled atmosphere heat treating furnace

—designed especially for tool rooms and small production

This new Cooley GA-3 electric is the first small furnace to provide atmosphere protection with a reasonable investment and low operating costs. The atmosphere is generated by cracking alcohol and water of proportions predetermined to suit the application. Steel may be clean hardened without decarburization, or may be carburized.

As a package unit, the Cooley GA-3 includes a fully wired temperature control panel and atmosphere generating unit. A sealed alloy retort with tightly closed door, automatic gas curtain and foot operated door mechanism are other features that help assure dependable, economical operation—with little adjustment required. Write or wire for catalog—investigate the possibility of this new furnace for your work.

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Cooley HEAT TREATING FURNACES

Norton Products For The Atomic Program

Over half a century ago Norton Company first used electric furnace techniques to produce fusion-stabilized materials. Through the years Norton fusion-stabilized materials such as fused alumina, silicon and boron carbides, fused magnesia, zirconia, etc., have been made more valuable to industry and have been raised to new standards of quality, uniformity, and purity.

Today, Norton keeps pace with the greatly increased demands of the atomic age for new high melting, chemically stable materials. In Cleveland in December, at the Atomic Exposition, a Norton exhibit will feature fusion-stabilized products and other products which have shown important potentialities for atomic energy applications:

Reactor Components

Stable boron compounds for reactor control elements and neutron shields. Ceramic and powder-metal fabricated components for fuel element applications.

Special Refractories

High-purity ceramic shapes, including crucibles and furnace components for processing metals and fuel elements.

Raw Materials

High-purity oxide, carbide, boride and nitride materials in granular and powdered form.

In addition, Norton is presently developing numerous experimental items. The Norton research and development organization includes an engineering staff experienced in atomic development — available for cooperation where electric furnace products may be of interest.

Norton high-melting materials have varied applications in many fields. In particular, they are the basic ingredients of the famous Norton Refractory Rx's — refractories *engineered and prescribed* for the widest range of industrial uses. For further information write, mentioning your requirements, to NORTON COMPANY, Refractories Division, 333 New Bond Street, Worcester 6, Massachusetts.

Above: Norton arc-type furnaces. *Below:* Norton resistance-type furnace.

NORTON
REFRACTORIES
Engineered... Rx... Prescribed
Making better products... to make your products better

variation in oil supply pressure. The use of this unit also permits a centralized, single valve operation for controlling the firing of multiple burners.
For further information circle No. 1725 on literature request card, page 32-B

Laboratory Furnace

A new micro-furnace has been announced by the Elizabeth Instrument Co. It is particularly suited to melting point temperature determinations, phase studies, sintering studies and other high temperature investiga-

tions. The specimen is under direct observation by a stereoscopic microscope at all times. The furnace will heat to 2000° F. in 45 min. and stabilizes quickly at temperature. The micro-furnace is self-contained and consists of the furnace unit, control console, microscope and illuminator.
For further information circle No. 1726 on literature request card, page 32-B

Arc Welding

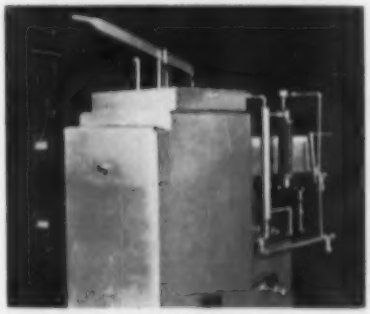
The new 800 ampere arc welder for inert-gas-shielded consumable-electrode welding was introduced by Air Reduction at the National Metal Show in Philadelphia, Oct. 17 to 21. This machine features constant arc voltage for all automatic machine welding applications employing constant speed wire feed. It contains a three phase transformer and a rectifier bank. Coils are aluminum wound, silicone and glass insulated. Forced draft cooling is provided by a fan with a reversible ball bearing motor. Arc voltage may be pre-set over a range of 15 to 44 arc volts. The voltage may also be pre-set to provide higher initial voltage for ease in establishing the arc. Once the arc is established, the voltage automatically adjusts to the pre-set value.
For further information circle No. 1727 on literature request card, page 32-B

Testing Machine

For tensile testing of fine metal wire and other materials, a new 200 lb. capacity testing machine has been announced by the Tinius Olsen Testing Machine Co. Flexure and compression tests can also be made with this machine. Any one of eight testing ranges from 0.4 to 200 lb. is available. In place of the normal dial indicator, recorder is mounted in the face of the machine. Both load and specimen extension are recorded on graph paper. Strain magnifications from 0.5 to 40 times are provided.
For further information circle No. 1728 on literature request card, page 32-B

Brazing Furnace

The Waltz Furnace Co. has announced an electric high-temperature furnace that was specially modified to incorporate a water-cooled, controlled-atmosphere cooling chamber. The furnace is capable of producing tempera-



tures up to 2400° F, and is suited for brazing operations and heat treatment of all high-speed steels. It has a working space 8 by 6 by 14 in.
For further information circle No. 1729 on literature request card, page 32-B

Infrared Heat

Pyrosil, Inc., introduced a new portable infrared heat lamp at the National Metal Show in Philadelphia, Oct. 17 to 21. The height of the lamp is adjustable from 48 to 66 in. Arc is 320 deg. Snap-out tubes are easily replaced.
For further information circle No. 1730 on literature request card, page 32-B

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What's New In Manufacturers Literature . . .

1745. Alloy Cast Iron
64-page bulletin A-71 on engineering properties and applications of Ni-Resist. Corrosion data compared with gray cast iron. *International Nickel Co.*

1746. Alloy Steel
40-page book on applications of heat treated, special alloy steel. *Jones & Laughlin*

1747. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

1748. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

1749. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

1750. Alloy Steel
Comparative tables of SAE and AISI standard steels and tentative standard steels. *Babcock & Wilcox*

1751. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1752. Aluminum Extrusions
28-page book on extruded aluminum products. Design, tolerances, applications. *Revere*

1753. Ammonia for Heat Treat
Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "The Nitriding Process", "Carbonitriding". *Armour*

1754. Analysis of Nickel Alloys
52-page Technical Bulletin T-36, "Methods for Chemical Analysis of Nickel and High-Nickel Alloys". *International Nickel*

1755. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

1756. Atmosphere Furnace
12-page bulletin on controlled atmosphere reciprocating hearth furnace for continuous hardening, light case carburizing, Ni-Carb ammonia-gas carburizing and other heat treating processes. *American Gas Furnace*

1757. Automatic Polishing
14-page, illustrated brochure describes automatic equipment for polishing, buffing and grinding. *Murray-Way*

1758. Barrel Finishing
32-page handbook on compounds for descaling, deburring, coloring, metal cleaning and rust inhibition. *Lord Chem.*

1759. Basic Materials
24-page booklet on Alundum, Crystolon, Magnorite, Norbide, zirconia, carbides, borides and other basic materials. Products made from them are listed. *Norton*

1760. Bearings
20 data sheets give special properties and case histories for new Rulon oil-free bearing material. *Dixon Corp.*

1761. Beryllium Copper
Bulletin 1 on available alloys, conditions tempers and tables of sizes and properties. *Penn Precision Products*

1762. Bimetal Applications
36-page booklet, "Successful Applications of Thermostatic Bimetal", describes 22 uses. *W. M. Chace*

1763. Blast Cleaning
8-page bulletin 1403 on liquid blast cleaning equipment. Drawings of cabinets. *Pangborn Corp.*

1764. Boron Additive
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

1765. Brass Alloys
Bulletin on powder metal copper-zinc alloys gives composition, strength, elongation and special features. *Dixon Sintaloy, Inc.*

1766. Brazing
New 12-page booklet tells how to silver braze with preformed rings. *Lucas-Milhaupt Engineering*

1767. Brazing Alloys
Bulletin on application of six types of copper and silver brazing alloys. *United Wire & Supply*

1768. Brazing Stainless Steel
Illustrated booklet, "Bright Annealing, Hardening and Brazing Stainless Steel", describes conveyor furnace and bright brazing alloy. *Sargeant & Wilbur*

1769. Brazing Titanium
Data sheet on use of a new flux for brazing titanium. *Handy & Harman*

1770. Bronze
Folder gives tables of properties, uses, forms and other data on phosphor bronzes. *Chase Brass & Copper Co.*

1771. Bronze Bearings
Brochure on bearing bronze. *American Smelting and Refining Co.*

1772. Buffing Compounds
Bulletin T-5 on buffing, liquid abrasive, cutting, coloring compounds. *Globe Compound Co.*

1773. Burners
8-page reprint No. 43 on Method for Improving Temperature Uniformity in Furnaces. *North American Mfg.*

1774. Carbides
84-page catalog of sintered carbides, hot pressed carbides, cutting tools, drawing dies, wear resistant parts. *Metal Carbides*

1775. Carbon Brick
Bulletin on properties, grades, applications of carbon and graphite brick for handling corrosive chemicals and molten metals. *National Carbon*

1776. Carburizing
16-page booklet on gas-carburizing processes and equipment. Discussion of suspended carburization, carbon restoration. *Surface Combustion*

1777. Castings
12-page booklet on casting costs and basic considerations in making good castings. *Herbert A. Reece and Assoc.*

1778. Centrifugal Castings
Folder on advantages of centrifugally cast thermalloy. *Electro-Alloys Div.*

1779. Ceramic Products
16-page booklet gives applications of porcelain, stoneware, graphite, alumina, in chemical equipment. *General Ceramics*

1780. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

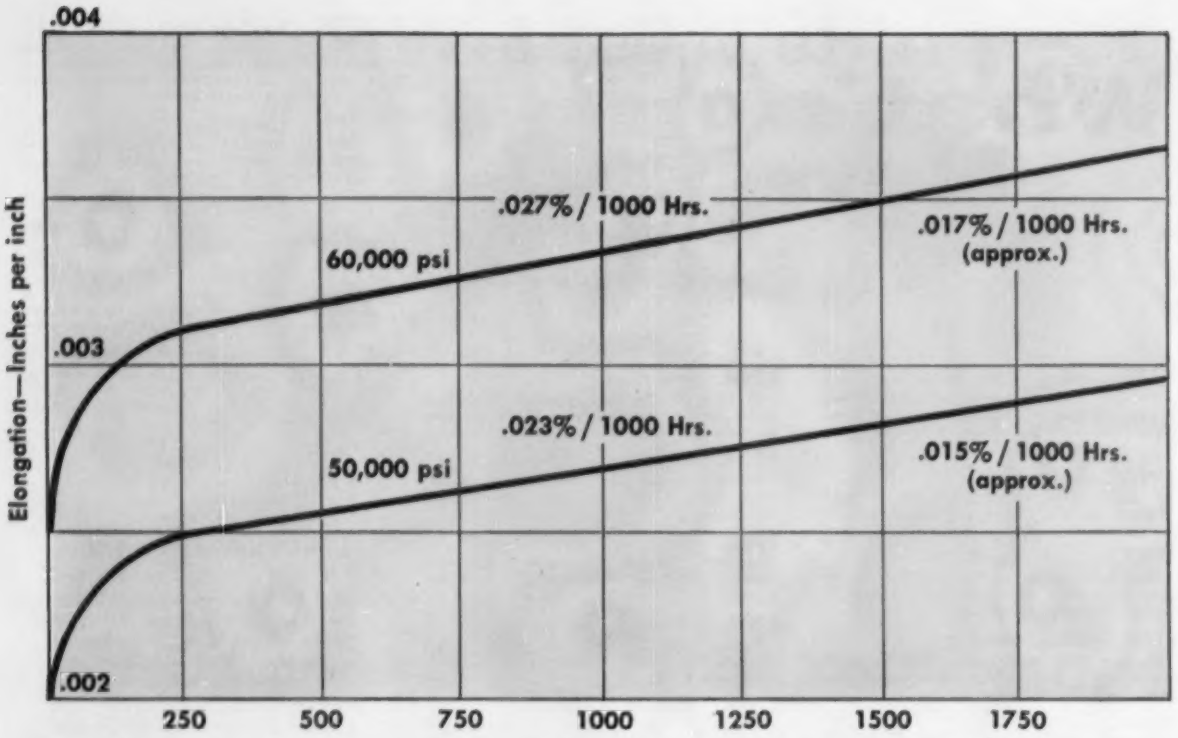
1744. Resistance Alloys
The alloys discussed in this 150-page loose-leaf book are designed for electrical resistance and electronic, chemical and mechanical applications. They consist of such compositions as 80% Ni – 20% Cr, 6% Ni – balance Cu, 80% Ni – 20% Co and 16 others. 70 tables give

complete data on the 19 alloys including resistance at different temperatures, for different shapes and with different coatings, weight of wire, properties and surface areas. In addition, the book contains temperature conversion tables; mechanical, electrical and thermal equivalents; ASTM standards that apply to electrical heating, resistance alloys and electronic tube materials; and a glossary. *Wilbur B. Driver Co.*

1781. Chromium Cast Iron
48-page book on effects of chromium on properties of cast iron. Data on production and uses. *Electro Metallurgical*

1782. Cleaner
Folder gives data on metal cleaners for use with water in still-tank or spray-washing equipment. *Solvents!*

1783. Cleaning
Data sheets on acid activators to promote removal of scale and oxides from steel and iron. *Swift Ind. Chem.*



Time-elongation creep curves at 900°F. show high creep resistance of "17-22-A" (S)

How to get high turbine alloy performance with low alloy steel

IF you produce gas turbine parts or other parts that operate at temperatures as high as 1000 degrees F., you may feel you have to use an expensive high alloy steel.

But you can make parts that will do the same job, and save strategic alloys, using "17-22-A" (S) steel made by the Timken Company.

This steel helps you cut costs because it contains only 3% alloy. Yet it gives maximum creep resistance up to 1000 degrees F. The graph above shows it at 900 degrees F.

There are other advantages. "17-22-A" (S) resists heat checking and thermal cracking. It is readily workable up to 2300 degrees F. It's easy to machine and weld. And maximum high temperature properties can be developed by normalizing and tempering, minimizing the possibility of distortion and quench cracking.

For complete information on "17-22-A" (S) steel, and its companion analysis, "17-22-A" (V), recommended for temperatures up to 1100 degrees F., write for Technical Bulletin No. 36A. And for help with your high temperature steel problems, call upon our technical staff. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING

1784. Cleaning
28-page bulletin on cleaning, phosphate coating, pickling machines and their operation. *Alvey-Ferguson*

1785. Cleaning Aluminum
12-page bulletin on cleaning process for preparing aluminum and magnesium for welding. *Northwest Chemical*

1786. Cleaning Compound
Bulletin B-6 on water displacing compound for producing unspotted, dry surfaces. *Apothecaries Hall*

1787. Coating
New 4-page booklet on spray coating for metals that preserves chemically clean surfaces. *Fidelity Chemical Products*

1788. Compressors
12-page data book 107-D gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

1789. Continuous Annealing
Article on continuous production annealing of screws, bolts, rivets. *Sunbeam Corp.*

1790. Contour Projectors
New 12-page catalog on six models of contour projectors for optical gaging. *Eastman Kodak Co.*

1791. Controllers
80-page catalog 8305 on nonindicating electric, electronic and pneumatic controllers for temperature, pressure and humidity. *Minneapolis-Honeywell*

1792. Controllers
Data sheets on indicating pyrometric controllers, proportioning controllers, portable controllers, pyrometer accessories. *West Instrument*

1793. Copper Alloys
40-page handbook on phosphor bronze, nickel silver, cupro nickel, beryllium copper. *Riverside Metal*

1794. Copper Alloys
40-page book on eleven copper alloys. Properties, cleaning, annealing. *Seymour Mfg.*

1795. Corrosion
8-page bulletin TR-537 on ways to avoid boiler tube corrosion. *Tubular Products Div., Babcock & Wilcox*

1796. Corrosion Resistant Alloy
Data sheet compares corrosion properties of Elgiloy and stainless steel. *Elgin National Watch Co.*

1797. Cut-Off Wheels
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

1798. Cutting Oil
Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service*

1799. Cutting Oil
Bulletin 963 on transparent cutting oil which is designed for use on a wide variety of steels. *Sun Oil Co.*

1800. Degreaser
40-page book on properties and use of trichlorethylene. Methods of handling and safety measures. *Niagara Alkali*

1801. Degreasers
Folders on vapor and solvent degreasers describe equipment and advantages. *Ramco Equipment Corp.*

1802. Dew Point Control
Bulletin No. 21-C on instrument which indicates, records and controls dew point automatically. *Ipsen*

1803. Die-Casting Machines
Case histories of companies using various types of die-casting machines. *Kux Machine.*

1804. Die Castings
Booklet on small zinc die castings. Types that can be made. Properties of zinc die casting alloys. *Gries Reproducer*

1805. Drawing and Forming
Booklet on functions and advantages of wax as a lubricant in metal forming operations. *S. C. Johnson & Son*

1806. Dryers
24-page bulletin No. 222 shows installations of air drying equipment in various industries. *Pittsburgh Lectrodryer*

1807. Ductile Iron
New 28-page bulletin gives advantages and applications of ductile iron. Properties. *International Nickel Co.*

1808. Electric Furnaces
Bulletin on electric heat treating furnaces gives summary of progress in furnace developments. *Holcroft*

1809. Electric Furnaces
Catalog of electric furnaces and ovens for hardening, tempering, annealing, drawing, drying, baking, enameling. *Cooley Electric Mfg.*

1810. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

1811. Electric Melting
Bulletin 527 on compact arc furnace. Melt time and power consumption for four alloys. *Detroit Electric Furnace*

1812. Electron Microscope
New 20-page booklet on special features and uses of electron microscope. *RCA*

1813. Extensometer
8-page bulletin on extensometers for sheet metal and wire, compressometers, defectometers and other accessories. *Baldwin-Lima-Hamilton*

1814. Extrusion Presses
8-page bulletin on aluminum extrusion presses describes the process and presses at work. *Watson-Stillman*

1815. Extrusions
New booklet on hot extruded and cold drawn sections gives advantages. *Jones & Laughlin*

1816. Extrusions
New 20-page booklet on extruded rod and bar stock in beryllium copper, beryllium aluminum and beryllium nickel alloys, beryllium metal and oxide. *Beryllium Corp.*

1817. Fatigue of Magnesium
18-page paper, "Plastic Flow and Work Hardening Phenomena in Magnesium Alloys During Fixed-Deflection Fatigue Tests". *Dow Chemical*

1818. Finishing
Catalog A-654 gives complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines. *R. C. Mahon*

1819. Finishing
52-page book "Advanced Speed Finishing" describes equipment for deburring and finishing. *Almco Div.*

1820. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g*

1821. Fluoroscopy
12-page booklet on fluoroscopy for nondestructive internal inspection. Explains image amplifier. *Westinghouse Electric, Industrial X-Ray Dept.*

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Temper requirements for the thin nickel strip (.002") used in sensitive electronic tubes were too exacting to be checked by the usual methods. So Somers carefully hand checks several samples from each lot by the ultra-precise "bend test" illustrated above.

Since 1910 Somers Brass Company has specialized in producing thin strip: nickel and its alloys below .020" and copper and its alloys below .012" with the tensile properties, fatigue resistance, drawing properties and many other requirements which only the most exacting standards of production and quality control can meet.

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NICKEL SILVER • PHOSPHOR BRONZE • BRASS

For over three quarters of a century, industry's nonferrous metal users have said . . .

"SPECIFY SEYMOUR. YOU KNOW IT'S GOOD!"

NICKEL SILVER ALLOYS

Alloy Number	10A7–10%	12A1–12%	12A4–12%	15A1–15%	18A1–18%	18A4–18%
Type	Forming	Forming	Spring	Forming	Forming	Spring
Copper	71.5%	65%	56.5%	65%	63%	55%
Nickel	10.0%	12%	12.0%	15%	18%	18%
Zinc	18.5%	23%	31.5%	20%	17%	27%
Melting Point (Liq.) °F	1950	1900	1870	1970	2030	1930
Density, Lbs./cu. in.	0.314	0.314	0.312	0.314	0.316	0.314
Aver. Linear Coefficient of Expansion per °F	0.0000090	0.0000090	0.0000091	0.0000090	0.0000090	0.0000093
Electrical Conductivity IACS	9%	8%	7.5%	7%	6%	5.5%
Modulus of Elasticity (Tension) Thousands p.s.i.	17,500,	18,000,	18,000,	18,000,	18,000,	18,000,

PHOSPHOR BRONZE ALLOYS

Alloy Number	971–3%	950–5% (A)	928–8% (C)	910–10% (D)
Copper	97%	95%	92%	90%
Tin	3%	5%	8%	10%
Melting Point (Liq.) °F	1950	1920	1880	1830
Density, Lbs./cu. in.	0.321	0.320	0.318	0.317
Aver. Linear Coefficient of Expansion per °F	0.0000099	0.0000099	0.0000101	0.0000102
Electrical Conductivity IACS	22%	16%	13%	11%
Modulus of Elasticity (Tension) Thousands p.s.i.	15,000,	15,000,	15,000,	15,000,

BRASS ALLOYS

Alloy Number	265	270	280	285	287	290
Type	Yellow	Cart. 70%	Low, 80%	Red, 85%	Jwlry, 87.5	Com. Br. 90
Copper	65%	70%	80%	85%	87.5%	90%
Zinc	35%	30%	20%	15%	12.5%	10%
Melting Point (Liq.) °F	1710	1750	1830	1880	1895	1910
Density, Lbs./cu. in.	0.306	0.308	0.313	0.316	0.317	0.318
Aver. Linear Coefficient of Expansion per °F	0.0000113	0.0000111	0.0000106	0.0000104	0.0000103	0.0000102
Electrical Conductivity IACS	27%	28%	32%	37%	40%	44%
Modulus of Elasticity (Tension) Thousands p.s.i.	15,000,	16,000,	16,000,	17,000,	17,000,	17,000,

SEND FOR YOUR FILE OF SEYMOUR TECHNICAL DATA

THE SEYMOUR MANUFACTURING COMPANY • SEYMOUR, CONN.

1822. Forging
20-page bulletin 355 on steam drop hammers. Dimension, designs, construction. *Erie Foundry Co.*

1823. Forgings
Folder on large forgings of carbon and alloy steel. *Struthers Wells Corp., Titusville Forge Div.*

1824. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

1825. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1826. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood Corp.*

1827. Furnace Maintenance
16-page "Maintenance Guide for Electric Heat Treating Furnaces" on preventive program. *Hevi Duty Electric*

1828. Furnaces
Data on luminous wall forging furnaces. *A. F. Holden*

1829. Furnaces
Folder giving drawings, dimensions, capacity, Btu. required for drawing, annealing, forging. *Gas Machinery*

1830. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

1831. Furnaces
Folder describes complete set up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1832. Furnaces
32-page catalog of industrial equipment includes furnaces and furnace accessories, special valves, mechanical equipment, materials handling equipment. *Salem-Brosius*

1833. Furnaces
High temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

1834. Furnaces, Heat Treating
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

1835. Furnaces, Heat Treating
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

1836. Gamma Ray Projector
Data on three radiation projectors for nondestructive testing and inspection. *Metal & Thermit*

1837. Gas Analysis
Data sheet on micro combustion furnace for carbon, hydrogen, nitrogen and oxygen analyses. *C. A. Brinkmann & Co.*

1838. Gear Tester
Folder gives description of tester and operating procedures. *Arch Instrument*

1839. Gold Plating
Article on analysis of gold and gold alloy plating solutions gives all currently available procedures. *Technic*

1840. Graphite
20-page brochure on significance of graphite as electrodes, anodes, molds and specialties in electrometallurgy and electrochemistry. *Great Lakes Carbon*

1841. Graphitic Tool Steels
48-page booklet on heat treating data, properties and 46 specific applications of graphitic tool steel. *Timken*

1842. Grinding Wheels
New 22-page booklet contains articles on how to select wheels for precision grinding of tool and constructional steels. *Norton Co.*

1843. Handling Devices
Pamphlets on clamps for lifting and handling. Their application to various industries. *Merrill Bros.*

1844. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1845. Hardness Tester
4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

1846. Hardness Tester
New bulletin on Wolpert-Gries Micro-Reflex hardness tester for loads from 10 to 3000 g. *Gries Industries, Inc.*

1847. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

1848. Hardness Tester
Literature on Brinell testing machines. *Detroit Testing Machine Co.*

1849. Hardness Testers
Catalog of testers for normal hardness, superficial testing, accessory and special testing and micro and macro hardness testing. *Wilson Mechanical Instrument*

1850. Heat Exchanger
Bulletin 124 on heat exchanger for cooling water, oil and other liquids and gases in many industries. *Niagara Blower*

1851. Heat Treating
16-page booklet on cost accounting for heat treating. *Metal Treating Institute*

1852. Heat Treating
Handy, vest-pocket data book has 72 pages of charts, tables, diagrams and factual data on steel specifications, heat treatments, etc. *Sunbeam*

1853. Heat Treating
24-page booklet on how to plan a tool room heat treating department gives several layouts of furnaces and auxiliary equipment. *Lindberg Engineering Co.*

1854. Heat Treating
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

1855. Heat Treating Fixtures
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

1856. Heat Treating Fixtures
New 32-page Catalog G-10 covers heat and corrosion resistant fabricated alloy products. Includes furnace muffles, trays, fixtures, retorts, pit-type furnace equipment, salt bath equipment, pickling and plating equipment. *Rolock, Inc.*

1857. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1858. High-Alloy Castings
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

1859. High-Strength Steels
48-page booklet on applications of seven nickel-copper high-strength low-alloy steels. *International Nickel Co.*

1860. High-Temperature Alloys
"Haynes Alloys for High-Temperature Service" summarizes all available data on 10 superalloys and lists physical and mechanical properties of two newly developed alloys. *Haynes Stellite*

1861. High-Temperature Steels
87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 high-temperature steels. *U. S. Steel*

1862. Identifying Stainless
Cardboard chart outlining systematic method for rapid identification of unknown or mixed stocks of stainless steels. *Carpenter Steel*

1863. Immersion Heating
4-page bulletin H-11 on correct selection, sizing and installation of equipment for immersion heating. *Eclipse Fuel Eng.*

1864. Impact Testing
Bulletin on machine for Izod, Charpy and tension testing. *Riehle*

1865. Induction Furnace
New 4-page folder on combination induction melting and holding furnace and automatic pouring unit. *Ajax Engineering*

1866. Induction Heating
24-page bulletin on low frequency induction heater for preheating and normalizing for welding. *Electric Arc, Inc.*

1867. Induction Heating
36-page bulletin on high-frequency induction heating unit for brazing, hardening, soldering, annealing, melting and bombarding. *Lepel*

1868. Induction Heating
New 12-page bulletin gives descriptions, technical data on various sizes. Water systems diagrams and standard accessory equipment. *High Frequency Heating Div., Lindberg Engineering*

1869. Induction Heating
60-page catalog tells of reduced costs and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

1870. Induction Heating
12-page Bulletin 13-A on high frequency induction furnace for forging, upsetting, spinning, annealing, hardening. *Ajax Electrothermic*

1871. Induction Heating
8-page bulletin on forging with induction heat includes case histories, benefits to the forging industry. *General Electric*

1872. Induction Heating Control
New Bulletin HT-1 on automatic temperature control for induction heating equipment. Types of control, components of induction heaters. *Minneapolis-Honeywell*

1873. Industrial Fans
Catalogs on various kinds of industrial fans — exhaust, multiblade, backward curve, for high temperatures. *Garden City Fan*

1874. Industrial Heating
20-page handbook classifies industrial ovens and gives pointers on oven selection. *Michigan Oven Co.*

1875. Infrared Analyzer
4-page data sheet on infrared gas analyzer describes instrument, its operation and maintenance. *Leeds & Northrup*

1876. Instruments
Catalog of temperature, pressure, recording, controlling and indicating instruments for the metal industry. *Taylor Instrument Companies*

1877. Insulation
40-page industrial products catalog on insulations, refractory products, and others. *Johns-Manville*

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the new superfine-grain drawing brass with the built-in finish

The secret is in the grain: Special methods of rolling and annealing produce in Formbrite* a grain structure so fine that often a simple color buff will bring it to a bright, lustrous finish.

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More and more companies are using Formbrite to cut their polishing costs and get superior products—at no extra cost over ordinary drawing brass. They often save more than the cost of the metal itself.

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Jarco Metal Products, Inc.: Polishing costs cut 40% in deep-drawn pen, pencil, and lipstick cases. Uniformity of Formbrite eliminated shutdowns for adjustments in long-run production.

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The American Brass Company

1878. Joining Stainless
24-page booklet on various welding methods, soldering, brazing, flame cutting and arc cutting of stainless. *Crucible Steel*

1879. Leaded Steel
Folder on lead-bearing, cold finished bars which machine about 80% faster than B1113. *LaSalle Steel*

1880. Leaded Steel
8-page bulletin gives chemical composition, mechanical properties and case studies showing machining production rates of Ledloy, lead bearing steel. *Ryerson*

1881. Lithium
Set of data sheets on lithium metal, lithium compounds. Uses of lithium in porcelain enamels, foundry, treatment of copper-base alloys. *Lithium Corp.*

1882. Lubricant
Bulletin 103A on fringe area lubrication with molybdenum disulfide lubricants for extreme bearing pressures and all temperatures. *Alpha Corp.*

1883. Lubricant
Bulletin 426 on use of colloidal graphite for forging, wire drawing, piercing, drawing, extrusion and other metalworking operations. *Acheson Colloids*

1884. Lubricant
8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Corp.*

1885. Machining Alloy Steels
24-page bulletin on economical combination of microstructure, tool form, cutting speed and feed for each machining operation. *International Nickel*

1886. Machining Copper
32-page booklet gives cutting speeds, feeds, rakes, clearances for more than 40 copper alloys. *American Brass*

1887. Machining Titanium
Four discussions of methods, problems, chip formation in grinding and machining titanium. *Cincinnati Milling Machine*

1888. Magnesium Alloys
Loose-leaf folder of data and tables on chemical specifications, properties, extrusion, machining operations. *Brooks and Perkins*

1889. Magnesium Finishing
128-page book describes all methods for finishing magnesium. *Dow Chemical*

1890. Melting Furnaces
28-page catalog on Heroult electric melting furnaces. Types, sizes, capacities, ratings. *American Bridge*

1891. Melting Guide
Selector guide for heating equipment and control for solder, tin and lead melting. *General Electric Co.*

1892. Metallographic Equipment
12-page catalog E-29 describes bright-field equipment for visual observation and photography. *Bausch & Lomb*

1893. Metallurgical Products
Chart of typical chemical analysis and commercial uses of zirconium oxides, silicates, soluble salts, metallurgical and foundry alloys. *Titanium Alloy Mfg.*

1894. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

1895. Microscopes
Catalog on metallograph and several models of microscopes. *United Scientific*

1896. Microscopes
New 8-page catalog D-1053 on Dynoptic metallurgical microscopes describes instruments and gives specifications. *Bausch & Lomb*

1897. Molybdenum
72-page book gives data on unalloyed molybdenum and four arc-cast alloys. Several pages of references. *Climax Molybdenum*

1898. Nickel Alloys
40-page book gives corrosion, physical and mechanical properties of Hastelloy alloys; 13 pages of fabrication data. *Haynes Stellite*

1899. Nickel Silver
60-page general catalog on nickel silver and phosphor bronze alloys in sheet, strip and coils. *Waterbury Rolling Mills*

1900. Nitriding Furnace
Bulletin 646R on carburizing and nitriding furnace giving atmosphere circulation to 1850° F. *Hevi Duty*

1901. Nitrogen Generator
New 6-page bulletin No. I-100 gives flow diagram and explains operation. *C. M. Kemp Mfg. Co.*

1902. Nondestructive Testing
Series of bulletins gives data on both ultrasonic and magnetic testing instruments. *J. W. Dice Co.*

1903. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

1904. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

1905. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1906. Phosphate Coating
12-page "Phosphate Coating Chemicals and Processes" gives data on paint bonding, rust proofing, protecting friction surfaces, improving drawing and extrusion. *American Chemical Paint*

1907. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1908. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

1909. Plating Machine
Bulletin B50-54 on automatic plating machine. How it works, maintenance, special adaptations, construction. *Wagner Bros.*

1910. Polishing
Folder on Kon-Toor abrasive polishing wheel for rotary, straight-line and semi-automatic setups. *Behr-Manning Div.*

1911. Polishing Materials
20-page booklet includes samples of emery, aluminum oxide and silicon carbide papers and 12 polishing cloths. *Buehler, Ltd.*

1912. Porous Chromium
12-page bulletin on hard, porous chromium coating for cylinder bores and bearing surfaces. *Van der Horst*

1913. Potentiometer
4-page data sheet on potentiometer for instrument checking and temperature measurements. *Leeds & Northrup*

1914. Potentiometer
Bulletin on high-speed recording dynamaster potentiometer. *Bristol Co.*

(Continued on p. 32A)

below 800° F.

Accurate

TEMPERATURE READINGS

in a few seconds . . .

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Low temperature Xactemp Pyrometer with rigid extension arm and surface tip thermocouple.

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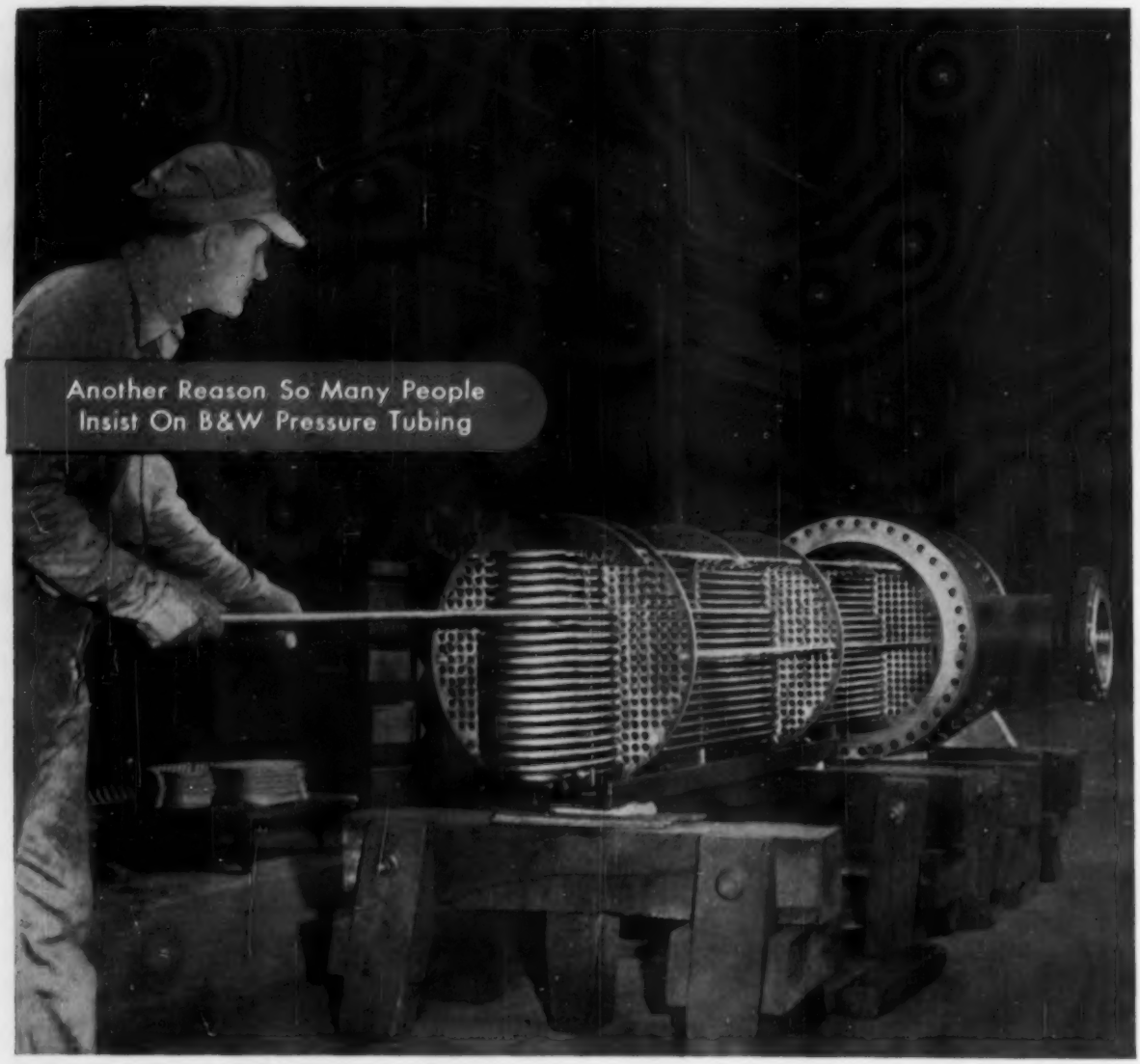

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(Continued from p. 31)

1915. Precision Casting
12-page book on alloy selection a
sign for precision casting. *Arwoo
cision Casting*

1916. Precision Casting
8-page bulletin on investment c
of various ferrous and nonferrous
Engineered Precision Casting

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metal protection. *American Ch
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quenching process gives results
wire quench test and in plant ope
Sinclair Refining Co.

1921. Radiation Detector
Bulletin 9320 on high-speed ra
detector gives operating principl
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1922. Radiation Protectio
12-page booklet on films for det
ing amount of radiation. Used in n
laboratories, nondestructive testi
oratories. *Du Pont*

1923. Rare Earths
8-page Progress Report Num
"Rare Earths in Iron and Steel M
Molybdenum Corp.

1924. Refractories
4-page bulletin on properties a
plications of corundum-base refr
Chas. Taylor Sons

1925. Resistance Testing
Bulletin 100 on production tes
measuring electrical resistance. *

1926. Resistance Weldin
24-page catalog on equipment
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bles and property and application
Ampco

1927. Rhodium Plating
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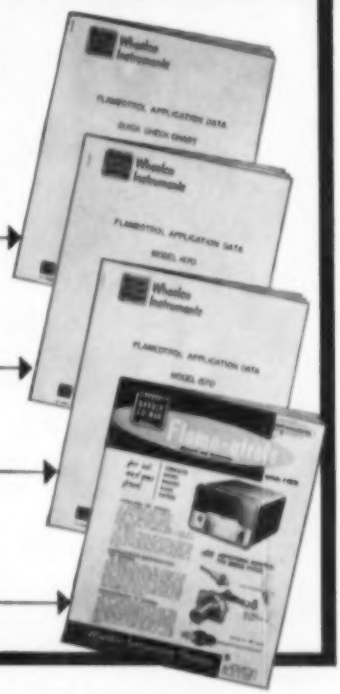
No. 3—Flame-otrol Application Data, Infrared "IR" System

No. 4—New Flame-otrol Catalog describes Controls, Sensing Systems, and Control Centers



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Complete flame supervision, no matter what the type of fuel, is available from Wheelco's broad line of industrial electronic combustion safeguard systems. Flame-otrol units can be applied to oil- or gas-fired furnaces, ovens, boilers, kilns, and driers with any type of conventional industrial sensing element.

Booklets offered above describe the flexibility of application possible with Wheelco Flame-otrol units and show how these units have been engineered to the job of flame detection and control. Years of research in the field of combustion safeguards have resulted in the engineering features now contained in the Flame-otrol system. Contributing to dependable performance of these systems are such features as: compact, plug-in design; heavy-duty construction; safety-type terminal strip; standard electronic tubes; and convenient checking strips.

Call your Wheelco field engineer for assistance in designing and specifying combustion safeguard systems.

NEW WHEELCO FLAME-OTROL

Wheelco Flame-otrols bring many improvements, including "plug-in" chassis, new safety-type terminal strip, "safe-start" operation, and convenient external test points to simplify circuit and voltage checking. Available with all conventional industrial-type sensing systems for improved flame supervision with gas, oil, or combination gas-oil firing. Bulletin F-6570.

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12-page book on alloy selection and design for precision casting. *Arwood Precision Casting*

1916. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1917. Protective Coatings
Guide to chemicals and processes for metal protection. *American Chemical Paint*

1918. Pure Metals
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New book on mechanism of quenching, properties of quenching mediums, cooling curves. *Gulf Oil*

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10-page book on new oils for the quenching process gives results on hot wire quench test and in plant operation. *Sinclair Refining Co.*

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1922. Radiation Protection
12-page booklet on films for determining amount of radiation. Used in research laboratories, nondestructive testing laboratories. *Du Pont*

1923. Rare Earths
8-page Progress Report Number 1, "Rare Earths in Iron and Steel Melting". *Molybdenum Corp.*

1924. Refractories
4-page bulletin on properties and applications of corundum-base refractory. *Chas. Taylor Sons*

1925. Resistance Testing
Bulletin 100 on production tester for measuring electrical resistance. *Rubicon*

1926. Resistance Welding
24-page catalog on equipment for resistance welding includes reference tables and property and application charts. *Ampco*

1927. Rhodium Plating
Data on properties, thicknesses required, costs, operation, applications. *Technic*

1928. Roll Formed Shapes
24-page Bulletin 1053 on designing, forming and producing shapes from ferrous and nonferrous metals. *Roll Formed Products Co.*

1929. Roll Forming
Bulletin 854 on roll forming of cold rolled shapes. *American Roller Die Corp.*

1930. Rust Preventives
12-page bulletin on water-soluble rust-preventive. *Production Specialties*

1931. Salt Bath Carburizing
5-page booklet on liquid carburizing with advantages and disadvantages of the salt bath process. *American Cyanamid Co.*

1932. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

1933. Salt Baths
Data on electric and gas salt bath furnaces. *Bellis*

1934. Salt Baths
32-page bulletin on salts for tempering, annealing, neutral hardening, martempering and carburizing. Heat treating data. *E. F. Houghton*

1935. Saws
Catalog C-53 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1936. Selective Carburizer
Bulletin on "No-Carb" for selective carburizing and prevention of decarburizing on high alloy steels during heating for hardening. *Park Chemical*

1937. Selective Heat Treating
Article in Heat Treat Review on mechanized selective hardening of yoke-type axle shafts. *Surface Combustion*

1938. Shotblasting
16-page "Primer on the Use of Shot and Grit". Problems of blast cleaning operations. *Hickman, Williams*

1939. Silver Brazing
48-page manual on all aspects of silver brazing applications and problems. *American Platinum Works*

1940. Sintered Carbides
New 24-page booklet on the characteristics of the various grades, for research and design engineers. *Kennametal*

1941. Sodium
New 28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

1942. Sodium Metal
24-page book on sodium in colloidal form, spread over inert solids of high surface area. Applications. *U. S. Industrial Chem.*

1943. Solder
Chart on special soft soldering alloys. *Alpha Metals*

1944. Spark Testing
20-page spark test guide features spark diagrams of 13 standard tool and die steels. *Carpenter Steel*

1945. Spinning
New booklet on hydrospinning techniques and machines. *Cincinnati Milling Machine Co.*

1946. Stainless Bars
28-page technical book on stainless steel bars includes processing information about cutting, welding, forging, upsetting, machining, and heat treating. *Allegheny Ludlum*

1947. Stainless Steel
Bulletin shows plates, forgings, sheets, tank heads, flanges. *G. O. Carlson*

1948. Stainless Steel
Data card 178 on stress-rupture properties of chromium-nickel stainless steel weld deposits. *Babcock & Wilcox Co.*

1949. Stainless Steel
40-page Design Handbook gives properties, specifications, applications, design data on springs and other design data. *Alloy Metal Wire*

1950. Stainless Tubing
40-page catalog, section 20, on alloys used, fabrication and working, pickling process. Sections on welding, soldering, brazing, machinability of heat resisting steels. *Superior Tube Co.*

1951. Stainless Wire
New 32-page aid to selection of proper stainless steel wire for particular application discusses austenitic, ferritic and martensitic grades. *Crucible Steel*

1952. Stampings
Practical suggestions how users of stampings can list specifications to get lower costs. *Laminated Shim Co.*

1953. Stamping
12-page catalog on stamping, drawing, forming and heading. *Plume & Atwood*

1954. Steel Terms
32-page dictionary of terms used in the steel industry. 180 definitions. Equilibrium diagrams, tables and figures. *LaSalle Steel*

1955. Stereomicroscopes
New 38-page Catalog D-15 shows value of three-dimensional microscopes for in-

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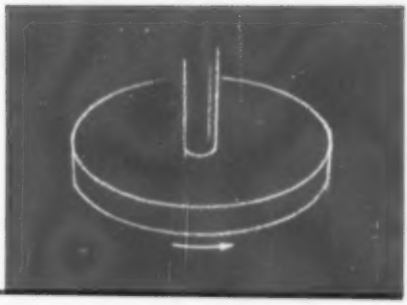

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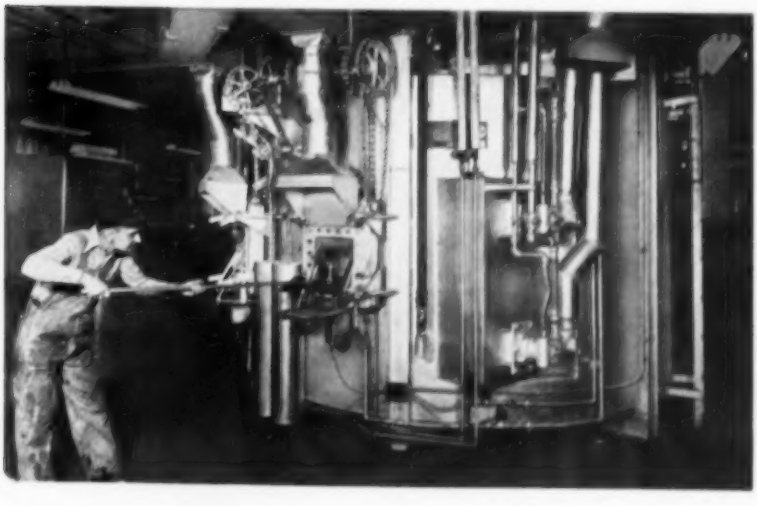

dustrial assembly lines and research laboratories. *Bausch & Lomb Optical*

1956. Strain Gages
8-page bulletin on how to measure strain, types of strain, types of member, environmental conditions. *Consolidated Engineering Corp.*

1957. Tanks and Linings
16 pages of data on tanks and corrosion-resistant linings for cleaning and plating solutions. *Chemical Corp.*

1958. Temperature Control
New 8-page bulletin on temperature control systems contains selection guide, terminology, types of control systems. *Wheelco Instrument Div.*

1959. Temperature Control
36-page bulletin P 1245 on new electronic instruments for recording and indicating variables. *Bristol Co.*

1960. Test Chamber
4-page booklet on controlled humidity chamber gives specifications. *Blue M Electric*

1961. Test Specimens
Data on machine for cutting test specimens to ASTM specifications. *Sieburg Industries*

1962. Tester
Bulletin 164 on Dyhedron, dynamic diamond tester for hardness and lubricity of materials. *Taber Instrument*

1963. Testing
12-page catalog on environmental testing and processing equipment including altitude, humidity, low temperature, explosion, sand and dust, cloud and pour units. *Bowser Technical Refrigeration*

1964. Testing Equipment
80-page illustrated catalog lists over 130 testing and measuring tools for laboratory and production-line use. *General Electric*

1965. Textured Steel
New booklet on surface rolled patterns in steel. *Sharon Steel Corp.*

1966. Thermocouple Wire
Bulletin on thermocouple wire and thermocouple extension wire lists sizes, metals, insulations. *Claud S. Gordon*

1967. Thermocouple Wires
4-page bulletin on ceramic insulated thermocouple wires and thermocouple extension wires. *Thermo Electric*

1968. Thickness Measurement
Data sheet 10.9-1a on sheet and coating thickness measurement on a continuous basis. *Minneapolis-Honeywell*

1969. Tin
20-page booklet describes mining of tin and its present use by American industry. *Malayan Tin Bureau*

1970. Tool and Die Steels
28-page guide to qualities and sizes available. *Uddeholm*

1971. Tool and Die Steels
26-page book on six oil and air hardening steels for high-production tools and dies. Many uses illustrated. *Bethlehem Steel*

1972. Tool Steel
36-page booklet on properties and applications of high speed steels, nonferrous cutting materials and carbides. *Allegheny Ludlum*

1973. Tool Steel Brand Chart
Wall chart listing over 300 popular tool steels by types. *Vulcan Crucible Steel Co.*

1974. Tool Steel Selector
Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

1975. Tool Steels
Bulletin on tool steels, hot work specialty steels, bar stock, billet, sand casting, drill rod, flat ground stock and tool bits. *Darwin & Milner, Inc.*

1976. Tubing
New 8-page catalog on carbon and alloy steel tubing of mechanical, pressure, airframe and aircraft mechanical quality. *Ohio Seamless Tube*

1977. Tubing
Bulletin No. 17 on shaped tubing describes that made in squares, rectangles, hexagons, flat ovals, ellipticals and partial rounds and where each is applicable. *Superior Tube*

1978. Tungsten
20-page bulletin on manufacture, properties and uses of tungsten. Flow chart of tungsten production. *Sylvania Electric Products*

1979. Ultrasonic Cleaners
Bulletin on ultrasonic cleaners for instruments. Advantages of use in manufacturing, maintenance and reconditioning. *Pioneer-Central Div.*

1980. Ultrasonic Cleaning
Folder on Sonogen ultrasonic generator for metal cleaning. *Branson*

1981. Vacuum Coating
Bulletin on principles, production steps, applications, equipment. *National Research*

1982. Vacuum Furnaces
New 8-page catalog No. 552 on vacuum furnaces for melting, heat treating, sintering, brazing. *High Vacuum Equipment*

1983. Vacuum Melting
Data on outgased ceramics for vacuum melting gives advantages and stock grades. *Products for Research & Production*

1984. Vacuum Metallizing
Bulletin 780 gives uses and advantages of vacuum metallizing, materials and properties of vacuum metallized coatings, the process, equipment. *Stokes*

1985. Vacuum Oven
New Bulletin 377 on vacuum oven discusses special features. *Precision Scientific.*

1986. Vacuum Pumps
New 52-page catalog No. 425 on high vacuum pumps contains formulas and tabular data. *Kinney Mfg.*

1987. Welding
Three bulletins on recently developed Fillerarc consumable-electrode, gas-shielded welding process. *General Electric*

1988. Welding Aluminum
Bulletin on electrodes for metal arc welding, welding rods for oxyacetylene welding and wire for inert arc welding. *Metal & Thermit*

1989. Welding Copper
24-page booklet on oxyacetylene, carbon-arc and metal-arc welding techniques for copper and copper alloys. *Revere*

1990. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

1991. Welding Rods
6-page bulletin on bronze welding rods. Table gives ASTM, AWS and Government specifications. *Titan Metal*

1992. Wire
11-page booklet on use of wire in construction of 36 products. *E. H. Titchener*

1993. Wire Products
Bulletin 111 on industrial wire cloth, conveyor belts and metal specialties. *Cambridge Wire Cloth Co.*

1994. X-Ray Equipment
Bulletins on No. 2 SPG X-ray detector describe specifications and advantages. *X-Ray Dept., General Electric*

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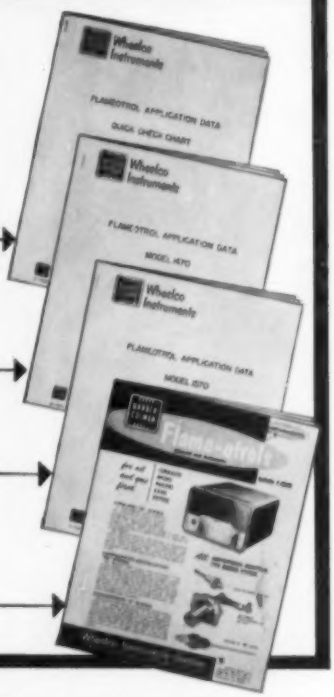

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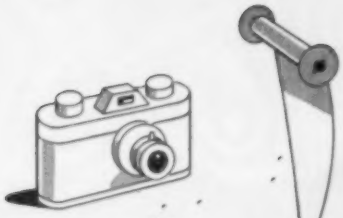

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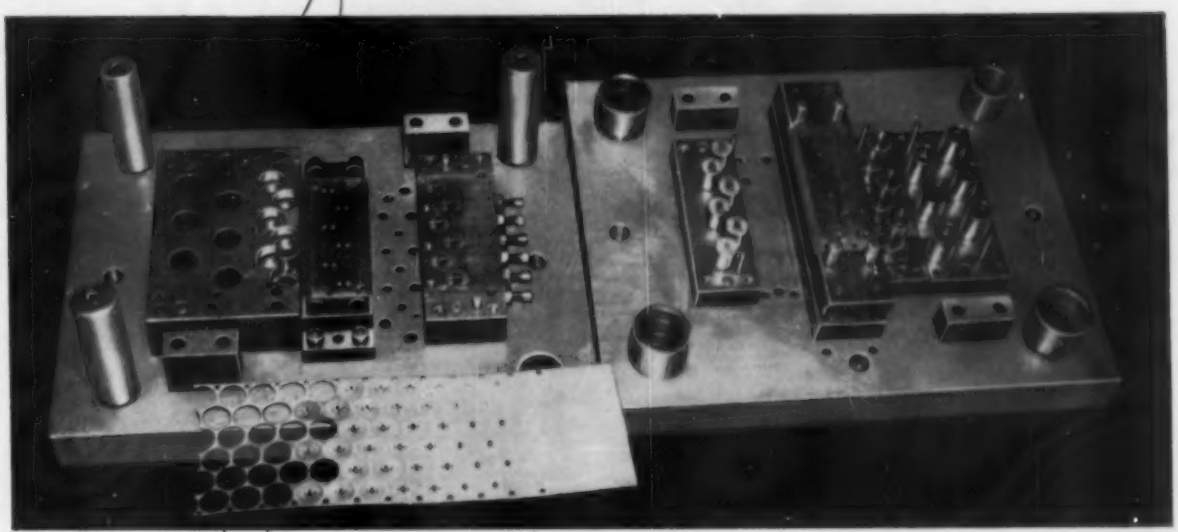

600,000 Film Spool Flanges PIERCED, EMBOSSED, STAMPED and BLANKED per Grind

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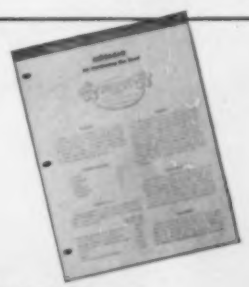
Operating at 130 strokes a minute, the big die has produced over 150,000,000 parts. Runs as high as 600,000 have been made between grinds. For this operation, Ontario is air cooled from a temperature of 1850 F, then tempered at 350 F for six hours. This results in a Rockwell C hardness of 60-62.

Ludlum Ontario is an air hardening die steel of the high carbon/high chromium type. It has all the desirable properties of such steels—resistance to abrasion, high hardness and excellent non-deforming characteristics. In addition, it is tougher but easier to machine than the higher carbon/high chromium types which are usually oil hardening.

For the finest in tool steel to help solve your cutting, forming, or blanking problems, call your nearest A-L office or distributor today, or write ***Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pennsylvania.***



Write for your
ONTARIO BLUE SHEET

A concise 4-page booklet of facts on the handling and shop treatments of Ontario. Included is complete information on forging, annealing, tempering, etc. and detailed laboratory data on physical characteristics. *Ask for your free copy.*

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For complete **MODERN** Tooling, call

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AL FINE TOOL STEELS SINCE 1854

(Continued from p. 31)

1915. Precision Casting
12-page book on alloy selection and design for precision casting. *Arwood Precision Casting*

1916. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1917. Protective Coatings
Guide to chemicals and processes for metal protection. *American Chemical Paint*

1918. Pure Metals
Data sheets on vacuum melted cobalt, copper, iron and nickel. *Vacuum Metals*

1919. Quenching Oil
New book on mechanism of quenching, properties of quenching mediums, cooling curves. *Gulf Oil*

1920. Quenching Oil
10-page book on new oils for the quenching process gives results on hot wire quench test and in plant operation. *Sinclair Refining Co.*

1921. Radiation Detector
Bulletin 9320 on high-speed radiation detector gives operating principles, applications, specifications. *Minneapolis-Honeywell*

1922. Radiation Protection
12-page booklet on films for determining amount of radiation. Used in research laboratories, nondestructive testing laboratories. *Du Pont*

1923. Rare Earths
8-page Progress Report Number 1, "Rare Earths in Iron and Steel Melting". *Molybdenum Corp.*

1924. Refractories
4-page bulletin on properties and applications of corundum-base refractory. *Chas. Taylor Sons*

1925. Resistance Testing
Bulletin 100 on production tester for measuring electrical resistance. *Rubicon*

1926. Resistance Welding
24-page catalog on equipment for resistance welding includes reference tables and property and application charts. *Ampco*

1927. Rhodium Plating
Data on properties, thicknesses required, costs, operation, applications. *Technic*

1928. Roll Formed Shapes
24-page Bulletin 1053 on designing, forming and producing shapes from ferrous and nonferrous metals. *Roll Formed Products Co.*

1929. Roll Forming
Bulletin 854 on roll forming of cold rolled shapes. *American Roller Die Corp.*

1930. Rust Preventives
12-page bulletin on water-soluble rust-preventive. *Production Specialties*

1931. Salt Bath Carburizing
5-page booklet on liquid carburizing with advantages and disadvantages of the salt bath process. *American Cyanamid Co.*

1932. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

1933. Salt Baths
Data on electric and gas salt bath furnaces. *Bellis*

1934. Salt Baths
32-page bulletin on salts for tempering, annealing, neutral hardening, martempering and carburizing. Heat treating data. *E. F. Houghton*

1935. Saws
Catalog C-53 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1936. Selective Carburizer
Bulletin on "No-Carb" for selective carburizing and prevention of decarburizing on high alloy steels during heating for hardening. *Park Chemical*

1937. Selective Heat Treating
Article in Heat Treat Review on mechanized selective hardening of yoke-type axle shafts. *Surface Combustion*

1938. Shotblasting
16-page "Primer on the Use of Shot and Grit". Problems of blast cleaning operations. *Hickman, Williams*

1939. Silver Brazing
48-page manual on all aspects of silver brazing applications and problems. *American Platinum Works*

1940. Sintered Carbides
New 24-page booklet on the characteristics of the various grades, for research and design engineers. *Kennametal*

1941. Sodium
New 28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

1942. Sodium Metal
24-page book on sodium in colloidal form, spread over inert solids of high surface area. Applications. *U. S. Industrial Chem.*

1943. Solder
Chart on special soft soldering alloys. *Alpha Metals*

1944. Spark Testing
20-page spark test guide features spark diagrams of 13 standard tool and die steels. *Carpenter Steel*

1945. Spinning
New booklet on hydrospinning techniques and machines. *Cincinnati Milling Machine Co.*

1946. Stainless Bars
28-page technical book on stainless steel bars includes processing information about cutting, welding, forging, upsetting, machining, and heat treating. *Allegheny Ludlum*

1947. Stainless Steel
Bulletin shows plates, forgings, sheets, tank heads, flanges. *G. O. Carlson*

1948. Stainless Steel
Data card 178 on stress-rupture properties of chromium-nickel stainless steel weld deposits. *Babcock & Wilcox Co.*

1949. Stainless Steel
40-page Design Handbook gives properties, specifications, applications, design data on springs and other design data. *Alloy Metal Wire*

1950. Stainless Tubing
40-page catalog, section 20, on alloys used, fabrication and working, pickling process. Sections on welding, soldering, brazing, machinability of heat resisting steels. *Superior Tube Co.*

1951. Stainless Wire
New 32-page aid to selection of proper stainless steel wire for particular application discusses austenitic, ferritic and martensitic grades. *Crucible Steel*

1952. Stampings
Practical suggestions how users of stampings can list specifications to get lower costs. *Laminated Shim Co.*

1953. Stamping
12-page catalog on stamping, drawing, forming and heading. *Plume & Atwood*

1954. Steel Terms
32-page dictionary of terms used in the steel industry. 180 definitions. Equilibrium diagrams, tables and figures. *LaSalle Steel*

1955. Stereomicroscopes
New 38-page Catalog D-15 shows value of three-dimensional microscopes for in-

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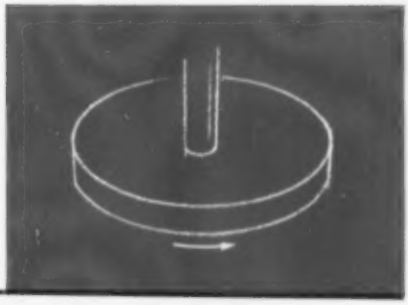


high production in small space

Production rates frequently bog down when floor space limitations prohibit large equipment purchases.

That's why—when the problem is heat treating—many companies turn to Holcroft for answers. Experience—imaginative engineering—versatility of products—all team up to provide answers.

For example, the solution to the problem above could conceivably be a rotary furnace; with one or two doors for loading and unloading and a rotating hearth which carries the stock through the heat treat cycle. The hearth can be of a heat-resistant alloy or a refractory material—can be suspended from above or supported from below. Rotary furnaces can be tunnel-type, grid-type, drum-type, or rotating retort.

Of course, this is only one of the many kinds of stock handling which might be suggested by Holcroft. Your problem probably will be different and Holcroft will have the answer.

Write today for a copy of Holcroft's illustrated book: "Blazing the Heat Treat Trail." It's bound to give you food for thought.

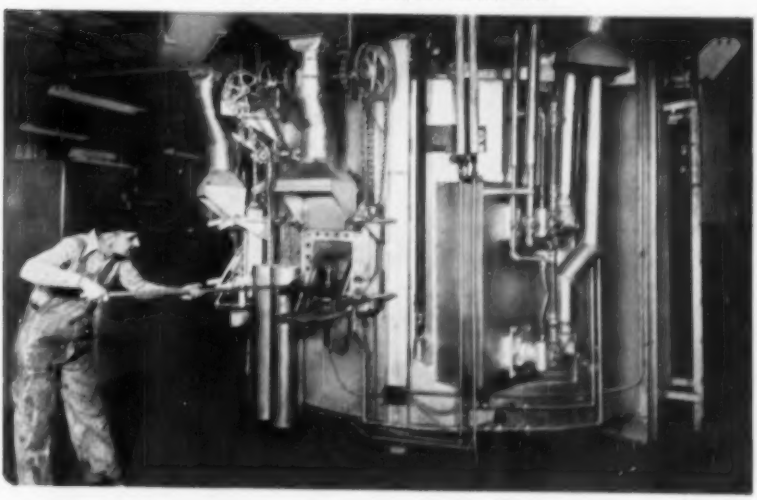
4575

HOLCROFT AND COMPANY

6545 EPWORTH BOULEVARD • DETROIT 10, MICHIGAN

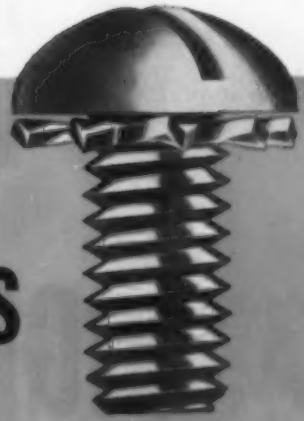
PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

CHICAGO, ILL. • CLEVELAND, OHIO • DARIEN, CONN. • HOUSTON, TEXAS • LOS ANGELES, CALIF. • PHILADELPHIA, PA.
CANADA: Walker Metal Products, Ltd., Windsor, Ontario



Mr. Emerich Bechtold, General Foreman of the Heat Treating Department, and a Gulf Sales Engineer examine the Sems as they emerge from a bath of Gulf Super-Quench.

uniform hardening of SEMS



Gulf Super-Quench

The Shakeproof Division of the Illinois Tool Works had a quenching problem with "Sems" — the well-known screw and lockwasher combination.

Sems are assembled — the lockwasher fitted on the screw—then heat treated. Attaining uniform hardness with conventional quenching oils was difficult, however, because of the difference in size of the heavier screw sections and the normal variations of the steel. The change to Gulf Super-Quench resulted in more uniform hardening, even in the heavier sections, without any cracking of the lockwashers.

Just another example of Gulf Super-Quench's ability to get faster quenching without cracking and distortion, maintain uniform hardness, and cut rejects on many different types of steel parts.

Have a Gulf Sales Engineer help you discover opportunities to put Gulf Super-Quench to work—profitably—in your shop. Contact your nearest Gulf office today and have him call.

Gulf Oil Corporation • Gulf Refining Company

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GULF SERVES INDUSTRY

another revolutionary development by La Salle

THE NEW

. . . gives HIGH STRENGTH . . .

"FATIGUE-PROOF" steel bars offer high strength in-the-bar . . without the expense and trouble of heat treating. Tensile strength is in the 140,000 to 150,000 p. s. i. range . . hardness which is related to this strength level is approximately 30 Rockwell "C."

"FATIGUE-PROOF" has uniform strength across the bar . . no soft centers. (This uniformity is maintained from bar to bar . . lot to lot.) This remarkable uniformity of strength makes "FATIGUE-PROOF" ideal for applications in the 140,000 to 150,000 p. s. i. range that formerly required heat treated carbon and alloy steels, either hot rolled or cold drawn.

With "FATIGUE-PROOF" you'll get the advantages of heat treating . . none of the disadvantages. In short, you'll get a better part at lower cost.

. . . yet it's EASY TO MACHINE

"FATIGUE-PROOF" *is* a free-machining steel bar . . without question. It machines at least 25% faster than annealed alloys . . 50% to 100% faster than heat treated alloys.

"FATIGUE-PROOF's" excellent machinability permits faster speeds, heavier feeds, better tool life . . your production rates will increase . . you'll get more parts per hour.

Distortion from machining is held to a minimum . . there is no reduction of tool life due to the higher speeds and heavier feeds . . and surface finish is greatly improved.

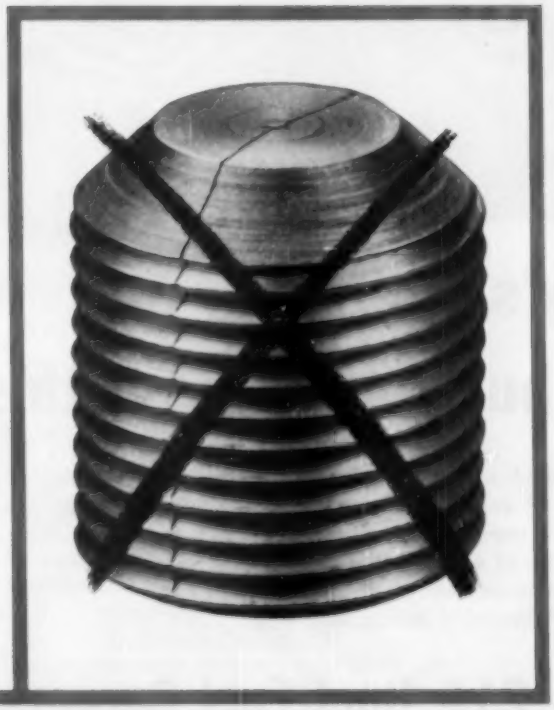
La Salle STEEL CO.

1424 150th Street, Hammond, Indiana

Manufacturers of America's Most Complete Line of *Quality* Cold-Finished Steel Bars

fatigue-proof STEEL BAR

WITHOUT HEAT TREATING



- *no quench cracks*
- *no distortion from heat treating*

With heat treating eliminated, the problems that accompany heat treating are avoided. Quench cracks become a thing of the past. Distortion and warpage from heat treating don't occur . . consequently time consuming and costly straightening and cleaning operations are not necessary.

You eliminate not only the cost of heat treating but also its disadvantages.

If you have parts where strength is a requirement . . you can save money and get away from problems by using "FATIGUE-PROOF." Our Sales Engineers will be happy to show you how this can be accomplished and provide samples for test purposes.

JUST PUBLISHED! Ask for your copy of the new 20-page booklet which gives additional information on the remarkable new "FATIGUE-PROOF."

LA SALLE STEEL CO.
1424 150th Street
Hammond, Indiana

Please send me your "FATIGUE-PROOF" Bulletin.

Name_____
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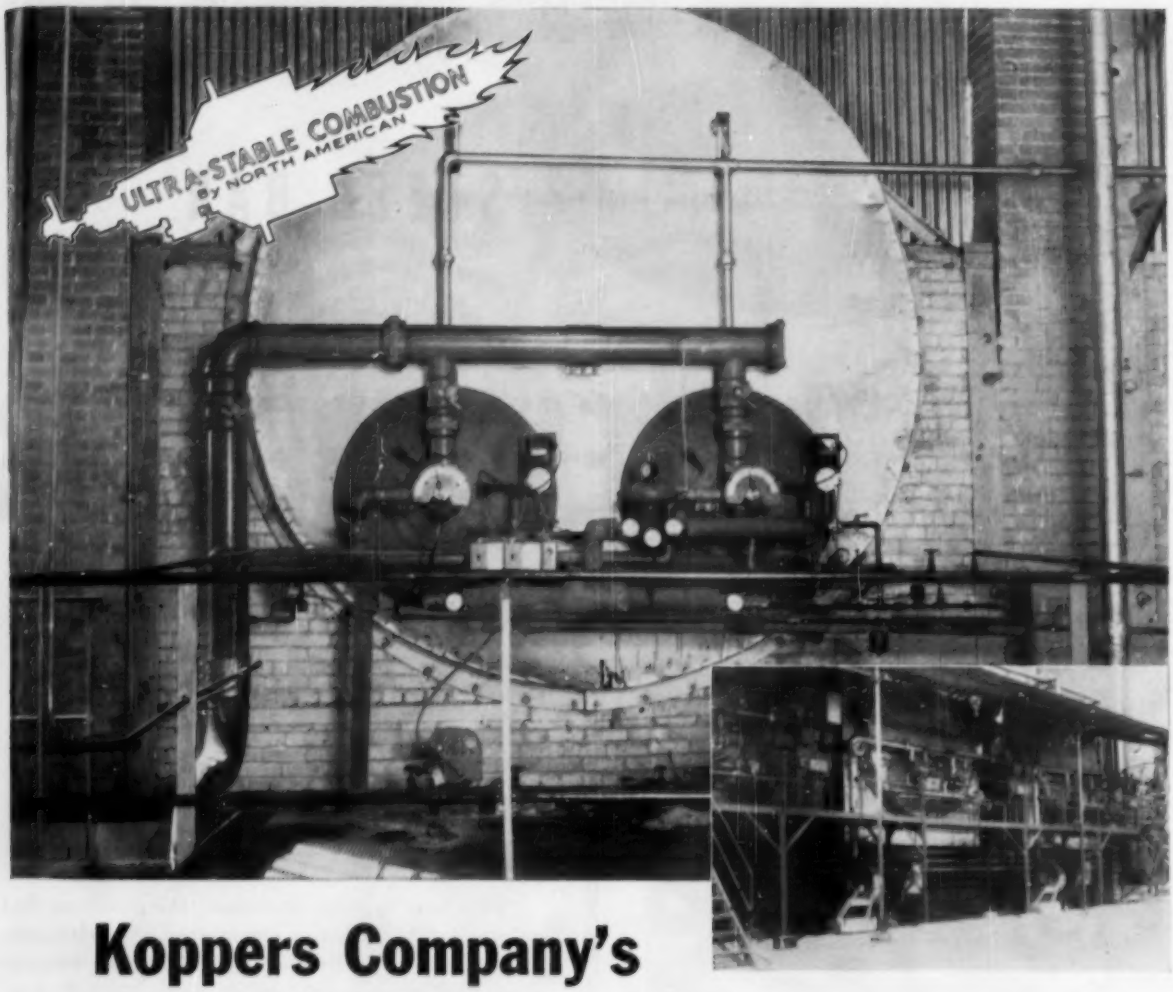

Koppers Company's tar stills demanded burners with all this:

✔ Stable flame with Bunker C Oil in cold combustion chamber ✔ Instantaneous change of fuels
✔ Immediate high fire rate upon light-up ✔ Same flame size and shape with all fuels
✔ 14 to 15% CO_2 with Bunker C Oil at all rates ✔ 5 to 1 turndown with any fuel
✔ Minimum maintenance ✔ Capable of easy lighting with torch or pilot
✔ Provision for all types of flame safety ✔ Short flame
✔ No carbon build-up ✔ Sealed-in burner mounting

North American Series 214 Dual-Fuel Burners met all these requirements....and then some!

NORTH AMERICAN COMBUSTION since 1917

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...with Park

NU-SAL NEUTRAL SALT

(Melting point 1230°F. / working range 1300-1650°F.)

and

THERMO-QUENCH SALT

(Melting point 290°F. / working range 325-1100°F.)

PART

Products are aircraft landing gear steel components, including forgings, arc and flash welded assemblies, basically tubular with complex lugs.

PROBLEMS

1. Eliminate decarburization and scaling.
2. Reduce distortion.
3. Reduce residual stresses resulting from heat treatments.

SOLUTION

Using an immersed electrode-type furnace 96" deep, these complex parts were austenitized in Park Chemical's Nu-Sal neutral salt at 1550°F. for 45 minutes. Previous method used 1½ hours. Quench at 400°F. is in Park Chemical's Thermo Quench Salt. Steels used are AMS 6324, AMS 6415 and AMS 6427.

Salt baths offer tremendous advantages over conventional heat treating methods. As much as 80% of all heat treating can be done in salt. Speedy handling and small floor space cuts costs. Quality is increased by eliminating quench cracks, scaling and decarb, while improving toughness and ductility.

Sixth in a series of advertisements describing Park processes on the job

• Liquid and Solid Carburizers • Cyanide, Neutral, and High Speed Steel Salts • Coke • Lead Pot Carbon • Charcoal • No Carb • Carbon Preventer • Quenching and Tempering Oils • Drawing Salts • Metal Cleaners • Kold-Grip Polishing Wheel Cement

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PARK CHEMICAL CO.

8074 Military Avenue • Detroit 4, Michigan

Send Free Bulletin on Neutral Salt Baths

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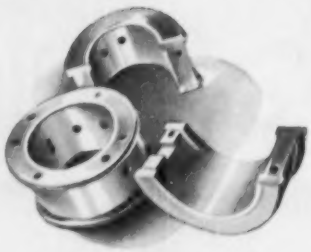
New uses for STRAITS TIN from MALAYA improve products—cut costs

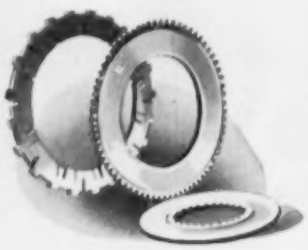
Soft drinks, quinine water—even wine—now go to market in handy disposable tin cans.



These new tin-aluminum bearings (up to 30% tin) are several times stronger than babbitt.

Tests show that a new tin-zinc plating alloy gives unusual corrosion protection to steel.

A new solder of tin and indium is being used to join glass to metal and metal to ceramics.



Tin is an important component of many sintered metal parts, such as these clutch facings.

And organotin compounds are the best stabilizers known for polyvinyl chloride plastics.

These are just six of hundreds of new ways Straits Tin is being used today. No other metal has tin's capacity for making other materials more efficient.

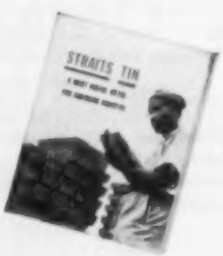
For example—

A tin coating on the fin coils of air-conditioning units helps prevent corrosion and odor accumulation. Modern engine pistons are often plated with tin to reduce friction between the piston and the cylinder liner. And a new way of electroplating bright tin-nickel offers for the first time a successful alternate to chrome on nickel-copper. Tin-nickel is both more corrosion resistant and more attractive than chrome. And it helps save scarce nickel.

Tin, of course, is not scarce. Nor is it likely to be in the future. Over one-third of the world's tin comes from Malaya. A great deal is there. And Malayan tin producers want to export it as much as American industry wants to use it.

Malaya is the keystone of Southeast Asia. With Malaya steadily winning its war against Communist guerrillas—with the new Manila Treaty and new U.S. Economic Aid Plans promising increased security against Communist infiltration in this vitally important area—American industry can count on a supply of tin fully as dependable as the supplies of other materials that are being produced in the Free World.

Straits Tin from Malaya is at least 99.87% pure—has been recognized as a standard grade for years. It is inert, nontoxic, friction and corrosion resistant. It is highly malleable, wets metals readily, and has a relatively low melting point (450°F.). Whatever your product or process may be, a careful reappraisal of the properties of Straits Tin may show you new ways to raise quality and lower costs.



A 20-page new booklet gives an informative report on Straits Tin and its many new uses today. Write for a free copy now.

Since February 1953, there have been no restrictions by the U.S. Government on the use of tin

MALAYAN TIN BUREAU

The Malayan Tin Bureau

Dept. CC5, 1028 Connecticut Ave., Washington 6, D.C.

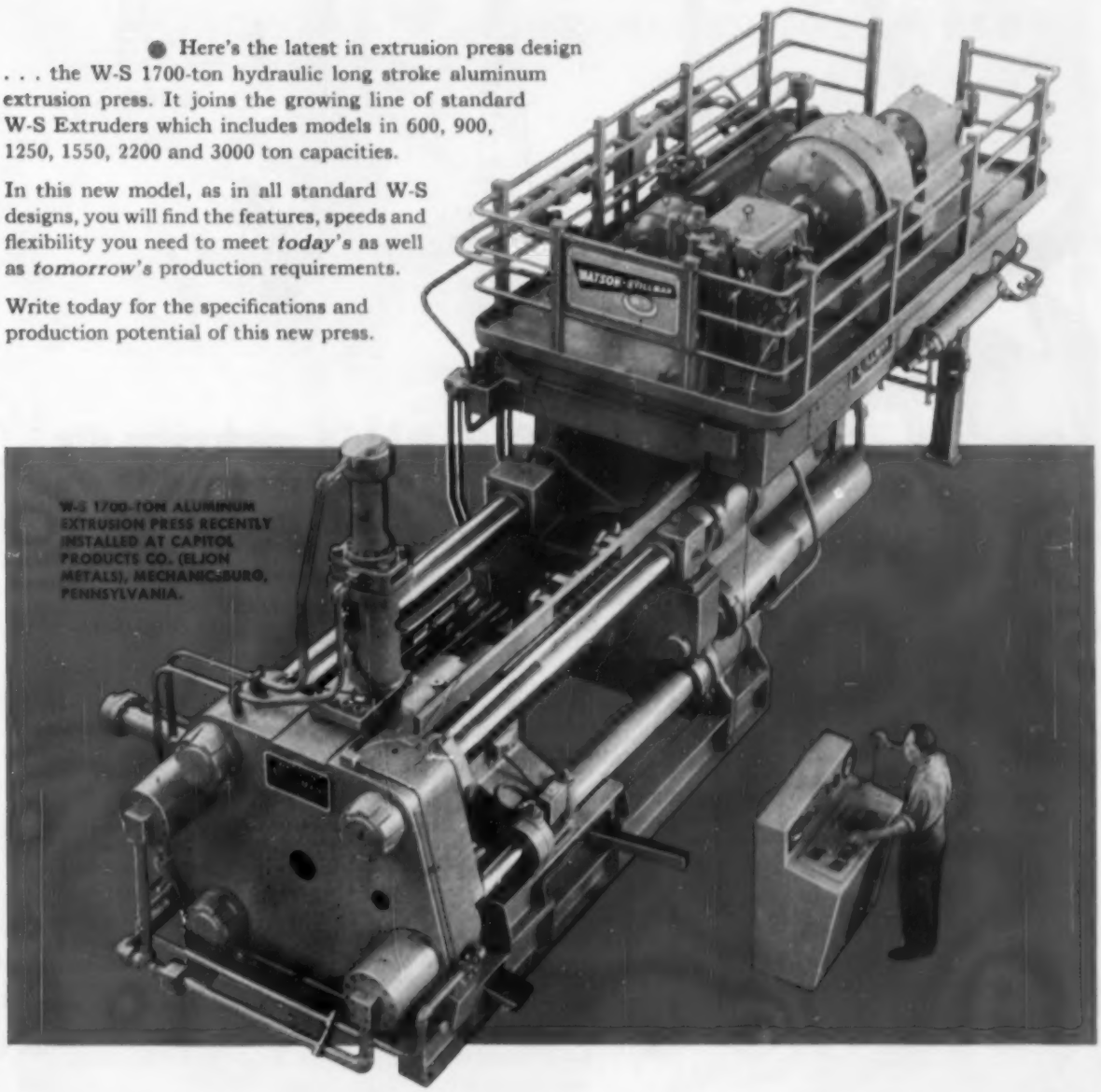
Aluminum

EXTRUSION PRESSES

● Here's the latest in extrusion press design . . . the W-S 1700-ton hydraulic long stroke aluminum extrusion press. It joins the growing line of standard W-S Extruders which includes models in 600, 900, 1250, 1550, 2200 and 3000 ton capacities.

In this new model, as in all standard W-S designs, you will find the features, speeds and flexibility you need to meet *today's* as well as *tomorrow's* production requirements.

Write today for the specifications and production potential of this new press.



W-S 1700-TON ALUMINUM EXTRUSION PRESS RECENTLY INSTALLED AT CAPITOL PRODUCTS CO. (ELJON METALS), MECHANICSBURG, PENNSYLVANIA.

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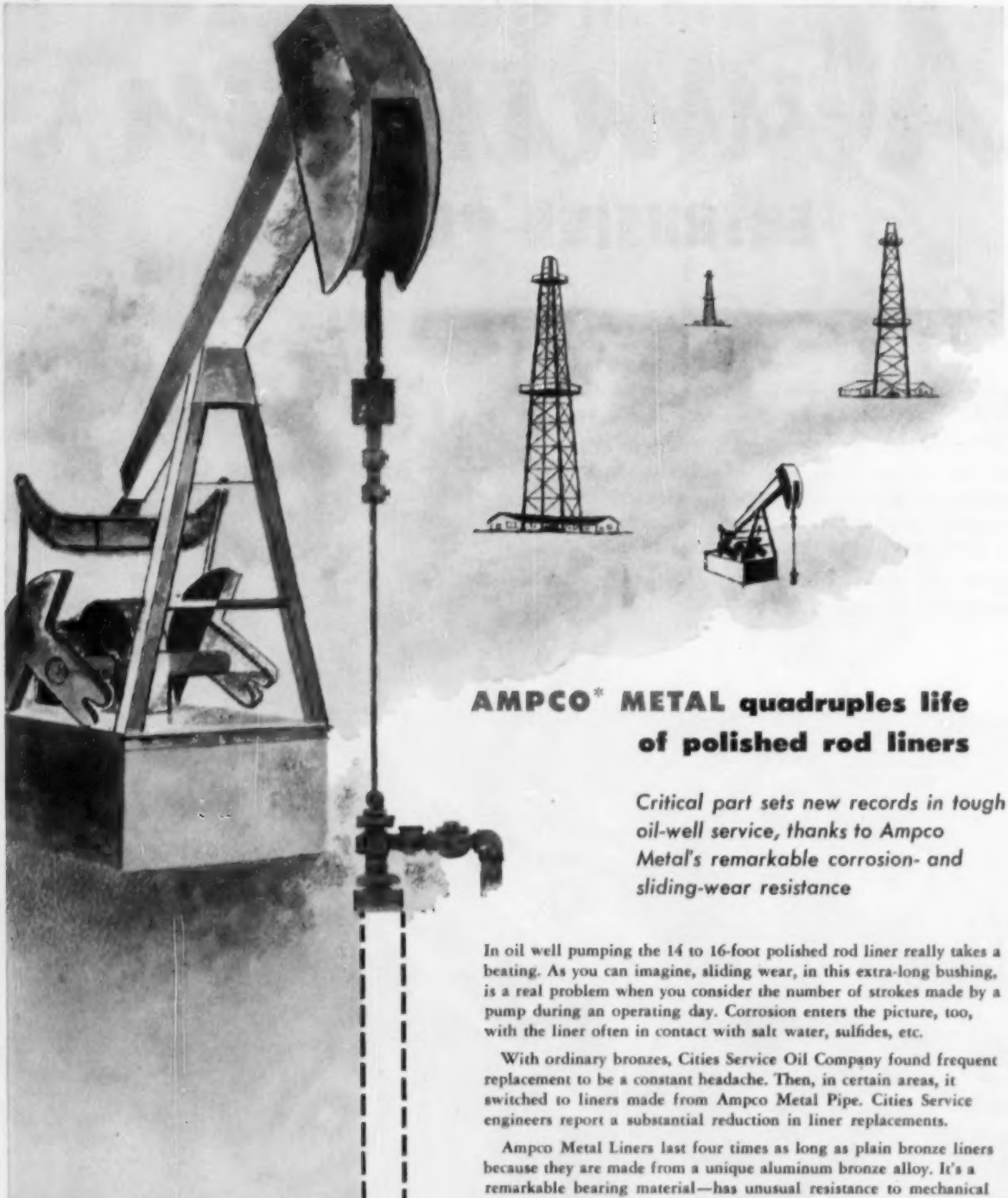

AMPCO* METAL quadruples life of polished rod liners

Critical part sets new records in tough oil-well service, thanks to Ampco Metal's remarkable corrosion- and sliding-wear resistance

In oil well pumping the 14 to 16-foot polished rod liner really takes a beating. As you can imagine, sliding wear, in this extra-long bushing, is a real problem when you consider the number of strokes made by a pump during an operating day. Corrosion enters the picture, too, with the liner often in contact with salt water, sulfides, etc.

With ordinary bronzes, Cities Service Oil Company found frequent replacement to be a constant headache. Then, in certain areas, it switched to liners made from Ampco Metal Pipe. Cities Service engineers report a substantial reduction in liner replacements.

Ampco Metal Liners last four times as long as plain bronze liners because they are made from a unique aluminum bronze alloy. It's a remarkable bearing material—has unusual resistance to mechanical wear. It withstands the corrosive effects of many acids and caustics. And when used as pipe it combats erosion from solids held in suspension.

Ampco pipe and tubing is available in all sizes, along with a complete line of flanges and fittings. Send coupon today for full information.

*Reg. U. S. Pat. Off.

AMPCO METAL, INC.
Dept. MP-12, Milwaukee 46, Wisconsin
D-45

I'm interested in knowing more about the wear- and corrosion-resistant properties of Ampco Metal. Please send me complete information.

Name..... Title.....

Company.....

Company Address.....

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AMPCO METAL, INC.
Sole Producer of Genuine Ampco Metal

Main Office and Plant
Milwaukee 46, Wisconsin
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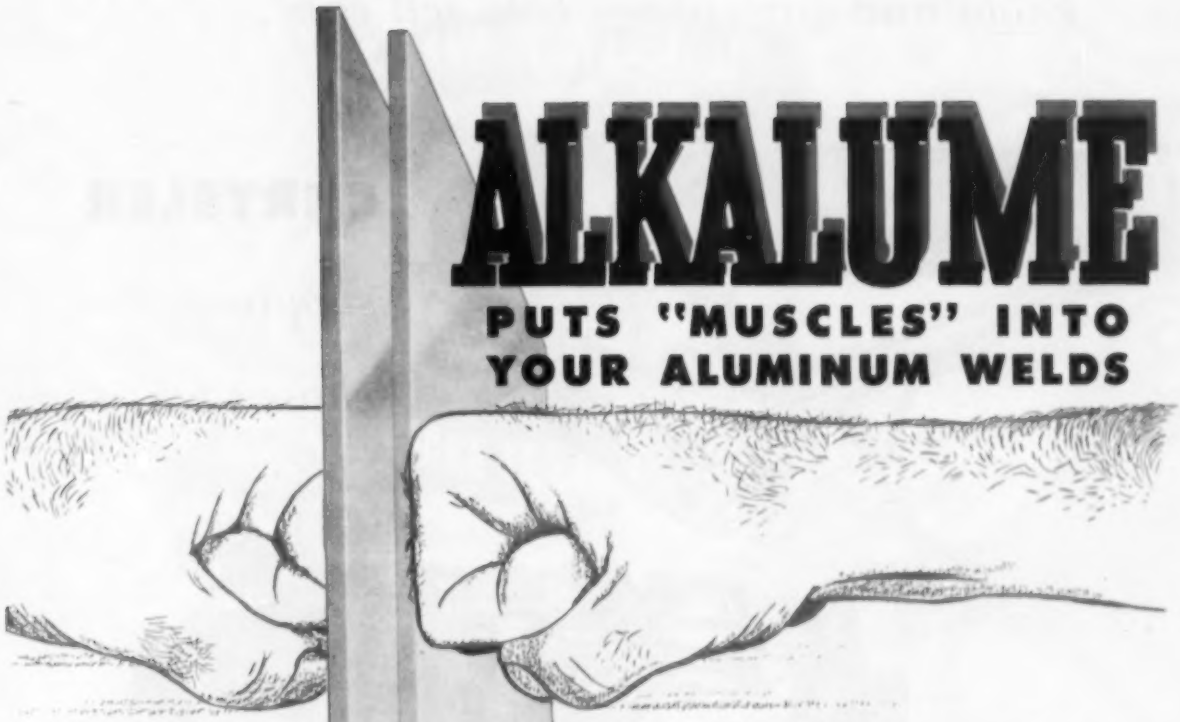
Burbank, California

ALKALUME

PUTS "MUSCLES" INTO YOUR ALUMINUM WELDS



ALKALUME—another great Northwest Chemical Process—is your answer to chemically clean aluminum necessary for successful welding. This safe, simple, economical process removes soils and oxides chemically—no wire brushes or other mechanical devices to waste metal and slow production. Surface resistance is reduced to a value of 0 to 10 microhms, and a resistance of less than 20 microhms will persist for days.

The Alkalume Process assures you a reliable—day after day—production of a uniformly weldable surface—regardless of alloy. Processed stock welds fast and easily producing welds that meet specified values for penetration and shear strength. In addition, with Alkalume Processed Stock, welds are made at lower pressure. The Alkalume Process reduces the number of tip dressings, thus giving you greater tip life.

ALKALUME'S outstanding success is another fine example of Northwest's ability to get the toughest jobs done by careful blending of good chemicals and experienced service control. The complete story of Alkalume or any of Northwest's fine line of cleaning chemicals is yours for the asking. A Northwest CLEANING SPECIALIST will gladly help you with your problems.

Got a problem? Let our cleaning experts help you!

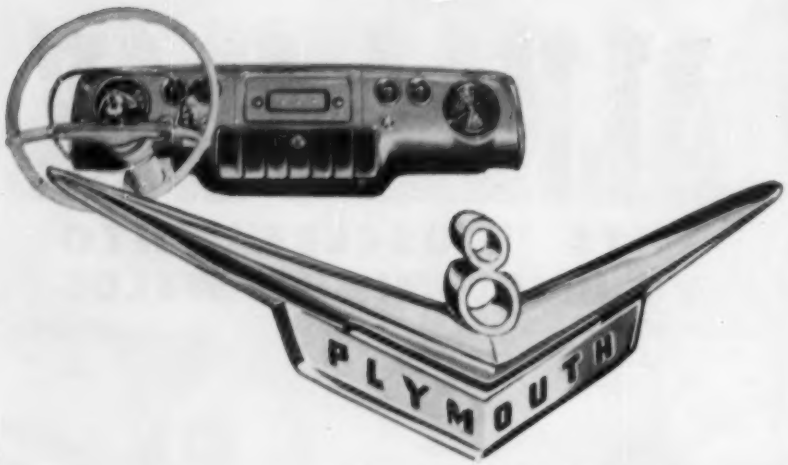
Write for complete literature on the ALKALUME Process

NORTHWEST CHEMICAL CO.

9310 ROSELAWN DETROIT 4, MICH.

pioneers in pH cleaning control serving you since '32

knobs and nameplates help sell cars . . .



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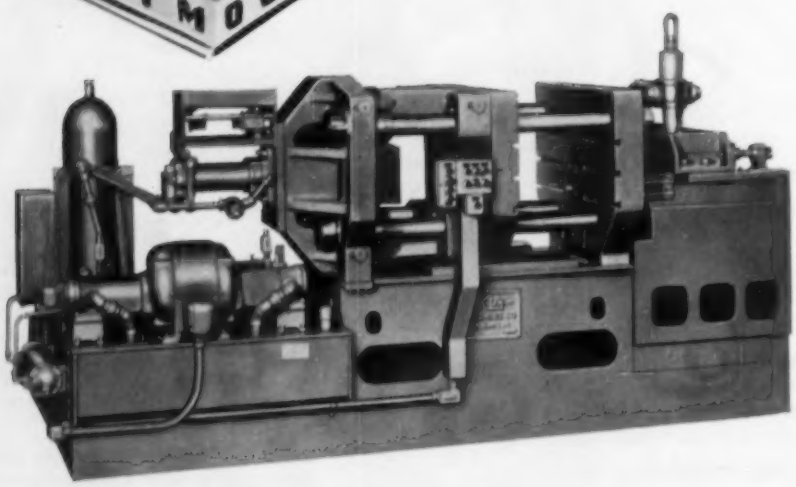

KUX DIE CASTING MACHINES

to get hardware finish quality castings

Big Chrysler Corporation contracts for die-cast trim parts are held by the Trilex Corporation of Wayne, Michigan, and Ajax Manufacturing Corporation of Detroit.

"The primary concern of the Chrysler Corporation is quality," says Mr. John Airey of Trilex. "That's why we chose KUX machines; we know they produce hardware finish quality parts."

"But Chrysler considers price as well as quality," said Mr. Milton K. Pitts of Ajax. "We choose KUX because they put us in a better position to compete on a cost-per-unit basis."

Whether your main concern is lower production costs, quality, or both, investigate the advantages of KUX machines. Quality die castings economically produced often make a tremendous difference in price and salability. KUX, first name in die casting machines, can help make that difference for you! Write for our NEW illustrated catalog.

MODEL BH-30 ILLUSTRATED

Hydraulically operated goose neck plunger type die casting machine for production of zinc, lead or tin castings.

KUX MACHINE CO. 6725 NORTH RIDGE AVENUE • CHICAGO 26, ILLINOIS

MAKE IT WEIGH LESS

N-A-X

HIGH-TENSILE STEEL

MAKE IT LAST LONGER

You can design light weight, longer life, and economy into your products by including N-A-X HIGH-TENSILE in your plans.

- It is 50% stronger than mild steel.
- It is considerably more resistant to corrosion.
- It has greater paint adhesion with less undercoat corrosion.
- It has high fatigue life with great toughness.
- It has greater resistance to abrasion or wear.
- It is readily and easily welded by any process.
- It polishes to a high lustre at minimum cost.

And with all these physical advantages over mild carbon steel—it can be cold formed as readily into the most difficult shaped stamping.

When you next start to redesign, get the facts on N-A-X HIGH-TENSILE. It's produced by Great Lakes Steel—long recognized specialists in flat-rolled steel products.

N-A-X Alloy Division

GREAT LAKES STEEL CORPORATION

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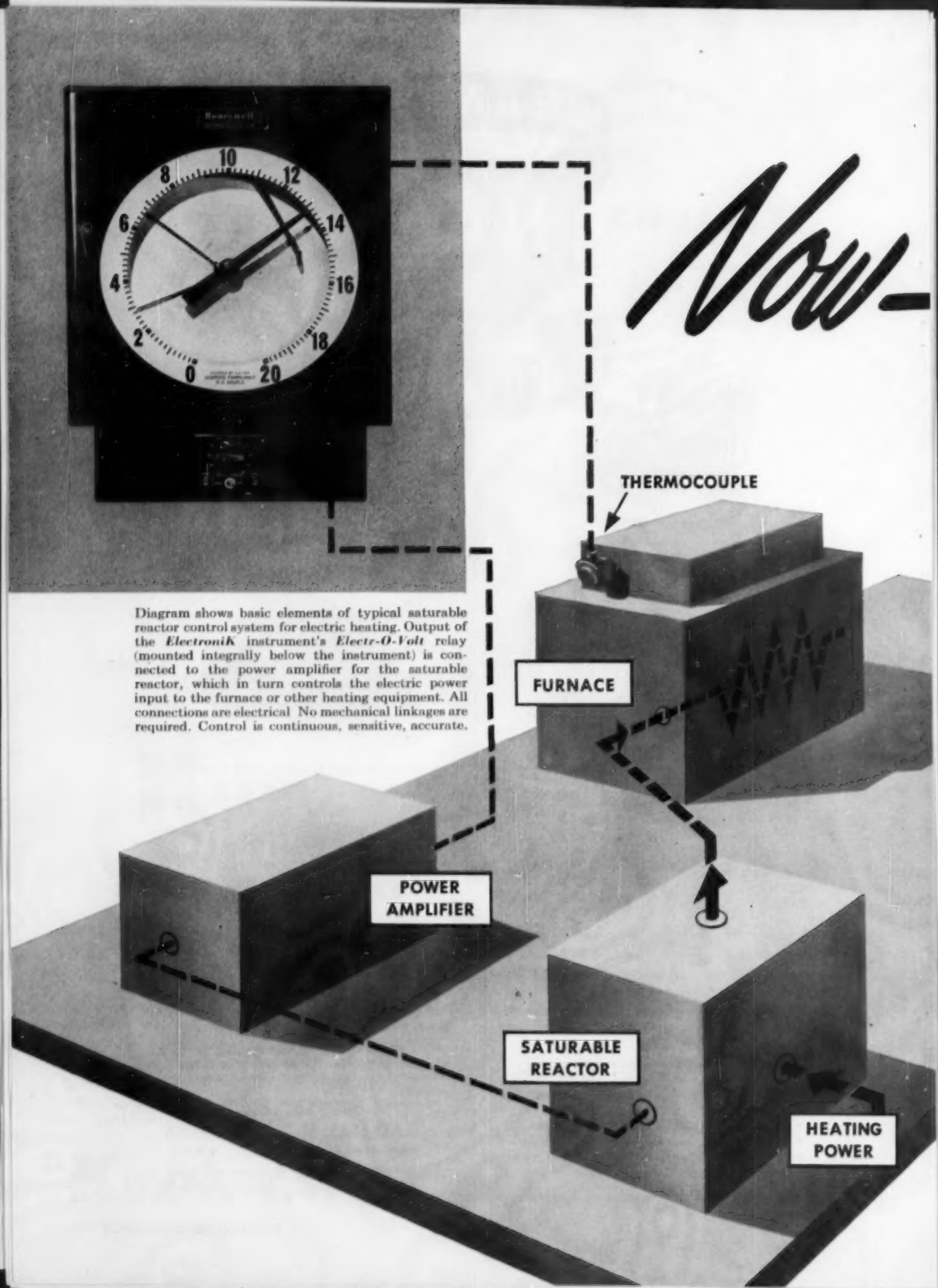

Diagram shows basic elements of typical saturable reactor control system for electric heating. Output of the *ElectroniK* instrument's *Electr-O-Volt* relay (mounted integrally below the instrument) is connected to the power amplifier for the saturable reactor, which in turn controls the electric power input to the furnace or other heating equipment. All connections are electrical. No mechanical linkages are required. Control is continuous, sensitive, accurate.

continuous, accurate control of electrically heated equipment

ElectroniK instrumentation with Electr-O-Volt* relay provides continuous throttling in saturable reactor control systems

You can now regulate temperatures of electrically heated furnaces, ovens, and similar processing equipment within exceptionally close tolerances, by using an advanced *ElectroniK* control system in conjunction with saturable reactors. This type of control eliminates the abrupt surges of power and the expense of contact replacement which are frequently objectionable factors of on-off or pulsed electric control.

Continuous control action. The *Electr-O-Volt* relay, actuated by the *ElectroniK* instrument, provides continuously variable control input to the saturable reactor power amplifier. This arrangement gives true proportional-plus-reset control action, which adjusts heat input to compensate for size of load, ambient temperature and other transient and long-term variations in heat demand.

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Broad range of use. *ElectroniK* control for saturable reactors is applicable to high-temperature heat-treating furnaces, reaction vessels and many other types of electrically heated equipment. It makes possible smooth, finely-adjusted regulation of electric power at high efficiency.

For a discussion of how this control can be applied to your specific problems, call your local Honeywell sales engineer. He's as near as your phone.

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● **REFERENCE DATA:** Write for Catalog 1531, "*ElectroniK* Controllers," and for new Bulletin 8428, "*Electr-O-Volt* Relay."

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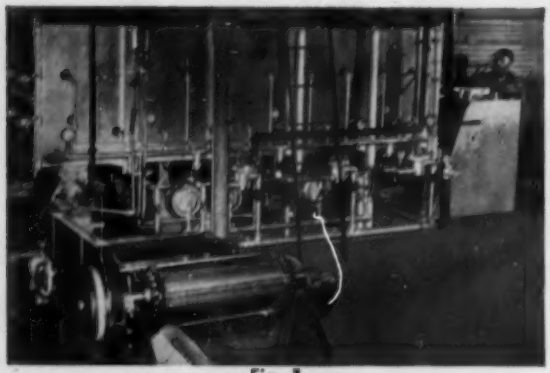

Fig. 1

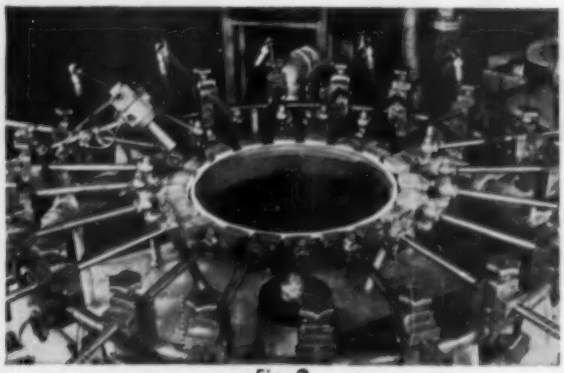

Fig. 2

An MTI commercial heat treater is located near you and is ready to serve your needs by performing "Custom-tailored" heat treating operations.

Because all members of the MTI are specialists with complete service facilities centralized in one plant, they are equipped to offer you a variety of heat treating processes—atmosphere hardening, carburizing, nitriding, annealing, cyaniding, etc.

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Fig. 2 illustrates a gas flame hardening unit featuring accurate temperature control and using two semi-circular gas manifolds mounted on movable carriages with 20 or more burner heads.

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Possessing such equipment together with many other specialized facilities and employing the trained personnel with technical knowledge and experience is the business of the commercial heat treater. Teamwork between you and the commercial heat treater can cut *your* costs.

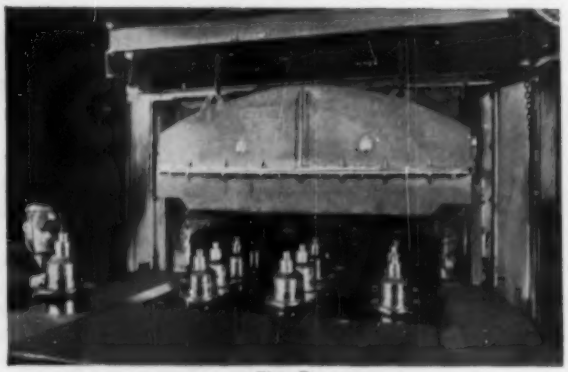

Fig. 3

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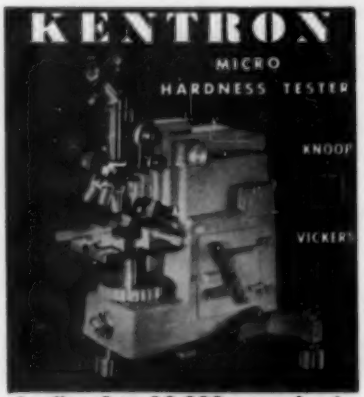

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Bulletin Board

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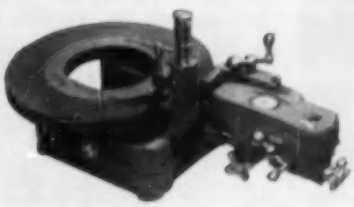

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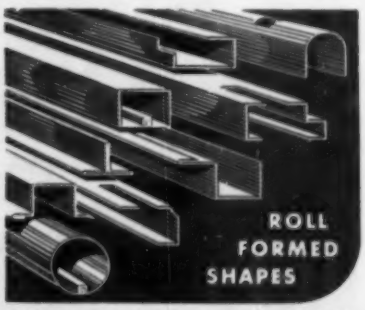

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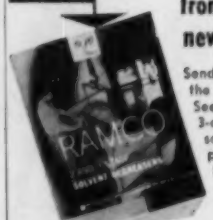

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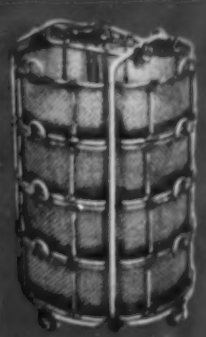

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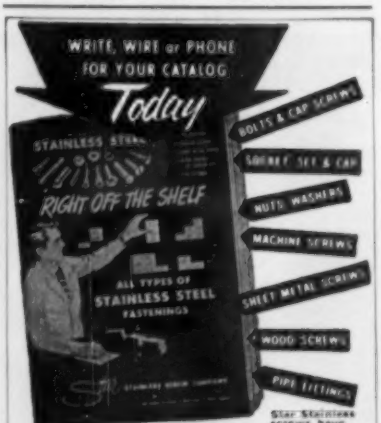

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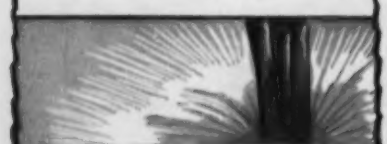

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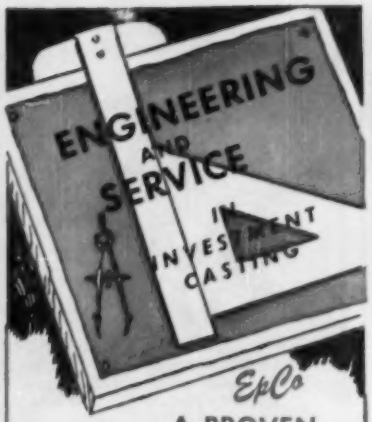

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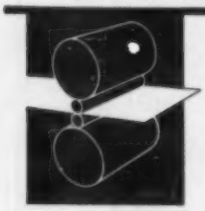

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Phone Reading 67321

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More than two thousand satisfied users WILL TESTIFY YOU

SAVE 3 WAYS WITH A LUCIFER FURNACE

1—Save on First Cost

CHECK THESE PRICES

Furnace Size	2000°	2300°
6x 6x12"	$ 500.00	$ 600.00
9x 9x18"	750.00	850.00
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Complete with 100% automatic electronic controls.

2—Save on Man Hours

Less operator attention needed—Lucifer controls are EXACT. They reach SPECIFIED heat rapidly and retain SPECIFIED temperature without variation. No special experience required when you use a Lucifer Furnace.

3—Save on Maintenance

Finest refractory materials are built into Lucifer Furnaces for better, more efficient heat retention. Elements are guaranteed, long lived, trouble free.

WRITE FOR FREE LITERATURE, specifications and price list of Lucifer Furnaces in wide range of sizes—top loading and side loading types. Engineering advice without obligation. Write, wire or phone today.

LUCIFER FURNACES, INC.
WEST MIFFLIN, PA.
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You've probably invested thousands of dollars in material equipment and ideas to cut costs and increase production. NOW for an investment of only $17.50 you can discover a new wonder working cutting oil. $17.50 delivers, freight prepaid, 10 gallons of Kelkut 202EP Soluble Oil. Cut back 3 to 4 times further than ordinary emulsifiable oils it will do work no other oil will do. It increases production and reduces rejects on any metal during Cutting, Drawing, Tapping, Threading, Grinding and Broaching. It's far superior in every characteristic. Case histories to back up claims. Send order on company letterhead with your signature and title. You'll be glad you did.

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Our specialty is equipment for handling parts through heat treating, quenching, pickling and kindred operations. For a generation we have designed and built baskets, trays, fixtures, hangers, carburizing boxes, retorts and every conceivable device for work handling. You can profit by our experience. Our engineers will gladly submit suggestions or work with your engineers to solve heat treating equipment problems. Write for catalog.

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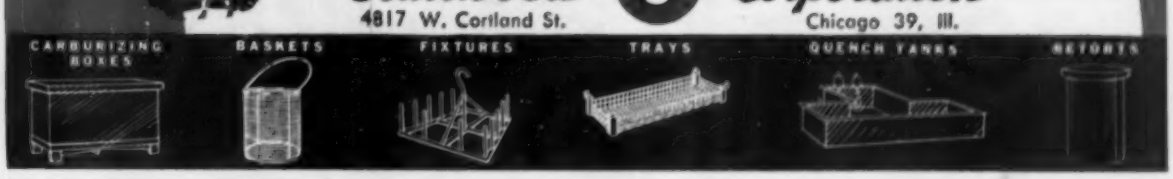

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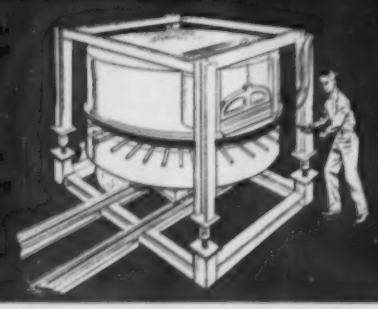
GASMACO Slot Type Rotary Furnace



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A MULTI-LAYER PRESSURE VESSEL is built up from concentric layers of relatively thin steel plate progressively wrapped, tightened and welded together around an inner, pressure-tight cylinder. Inner layer is made like any solid wall vessel. This highly efficient, patented construction makes possible economies—*with safety and flexibility of design*—in heavy-wall vessels intended for use at extremely high pressures. United States Steel helped the manufacturer develop a special steel for these Multi-layer vessels.

saves money on heavy-wall, high-pressure vessels

With its ingenious Multi-layer pressure vessels, A. O. Smith Corporation opens up almost unlimited possibilities to the design engineer for commercial-size vessels for unusually high pressures—from 7500 to 30,000 psi. Instead of using hard-to-fabricate, heavy-gauge plates A. O. Smith builds up the thick walls of these vessels with multiple layers of thin steel. As a result, welding conditions are improved and stress relief is not needed. Consequently, Multi-layer fabrication of heavy wall cylinders is more economical.

USS METALLURGICAL SERVICE HELPED SOLVE THE PROBLEM

When A. O. Smith engineers first conceived Multi-layer construction, process pressures were within limitations of standard A.S.T.M. steel strengths. However, as pressure demands increased, A.O. Smith needed a new and very special steel. And that is where United States Steel came to their aid. We helped them develop a high-tensile, high-yield strength, low-alloy plate steel with a minimum ultimate strength of 105,000 psi., a minimum yield strength of 70,000 psi., and good weldability.

HELP FOR YOU

When you have any sort of steel problem, let USS metallurgists help you with it–whether you need a special steel or just want to be sure you have the *very best* of the standard AISI analyses for your job. Phone our nearest district sales office. Or write United States Steel, Room 4987, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

See The United States Steel Hour. It's a full-hour TV program presented every other week by United States Steel. Consult your local newspaper for time and station.

UNITED STATES STEEL CORPORATION, PITTSBURGH • COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
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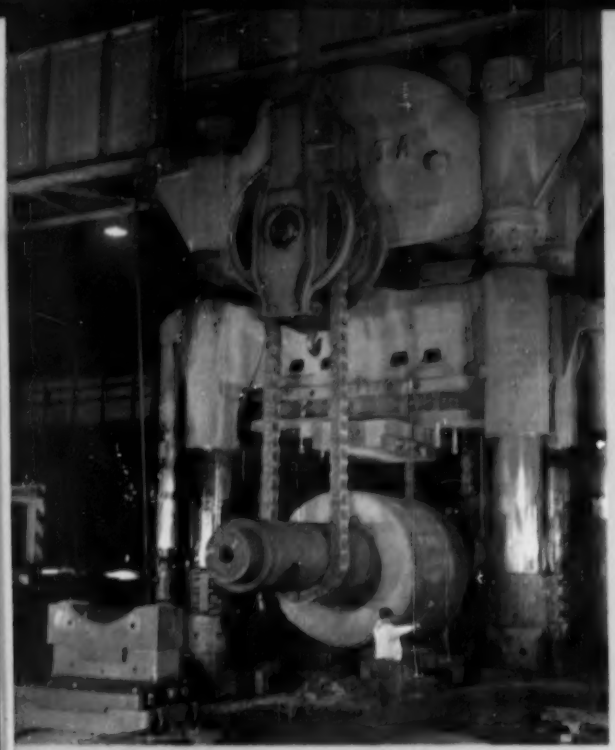
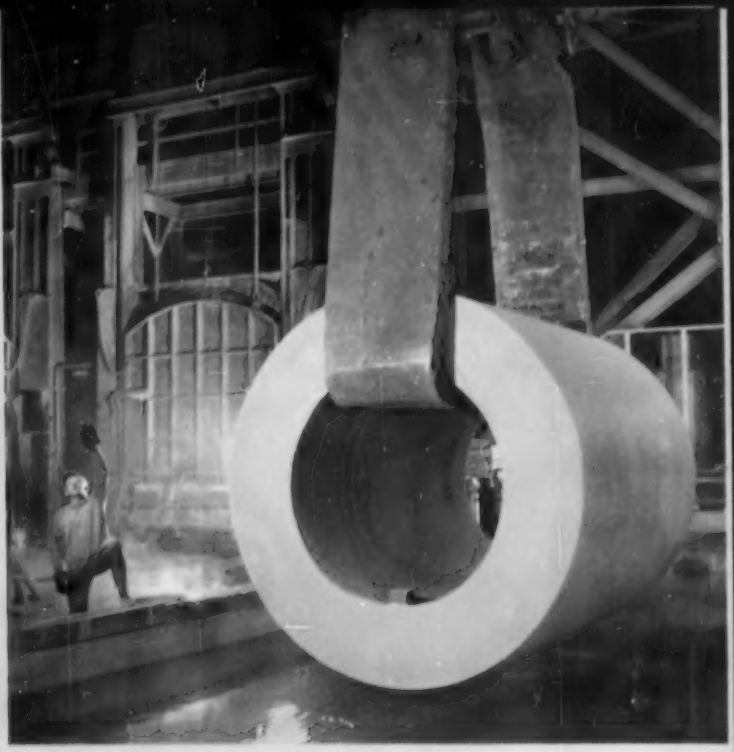
ELECTRIC FURNACE OR OPEN HEARTH

COMPLETE PRODUCTION FACILITIES IN CHICAGO OR PITTSBURGH

UNITED STATES STEEL



Here, one of the cylinders is being forged on the 7,000-ton press. Masterful work on the mandrel and precision manipulation of the press provide proper thickness/diameter ratio.



The cylinder (largest of its kind ever forged) is about to be lowered into the water quench tank after heat treating.

GE gets ready to make some big crashes

General Electric's Large Steam Turbine-Generator Department recently installed a high-speed burst pit to investigate the bursting characteristics of wheels and rotors. Model forged turbine and generator shafts and other partial and full scale parts will be spun at speeds up to 25,000 rpm or until they burst.

The big burst pit includes two concentric forged steel cylinders, made by the Homestead Forgings Division of U. S. Steel. These 60-ton cylinders must possess a strength that almost defies description because tremendous forces are at work here.

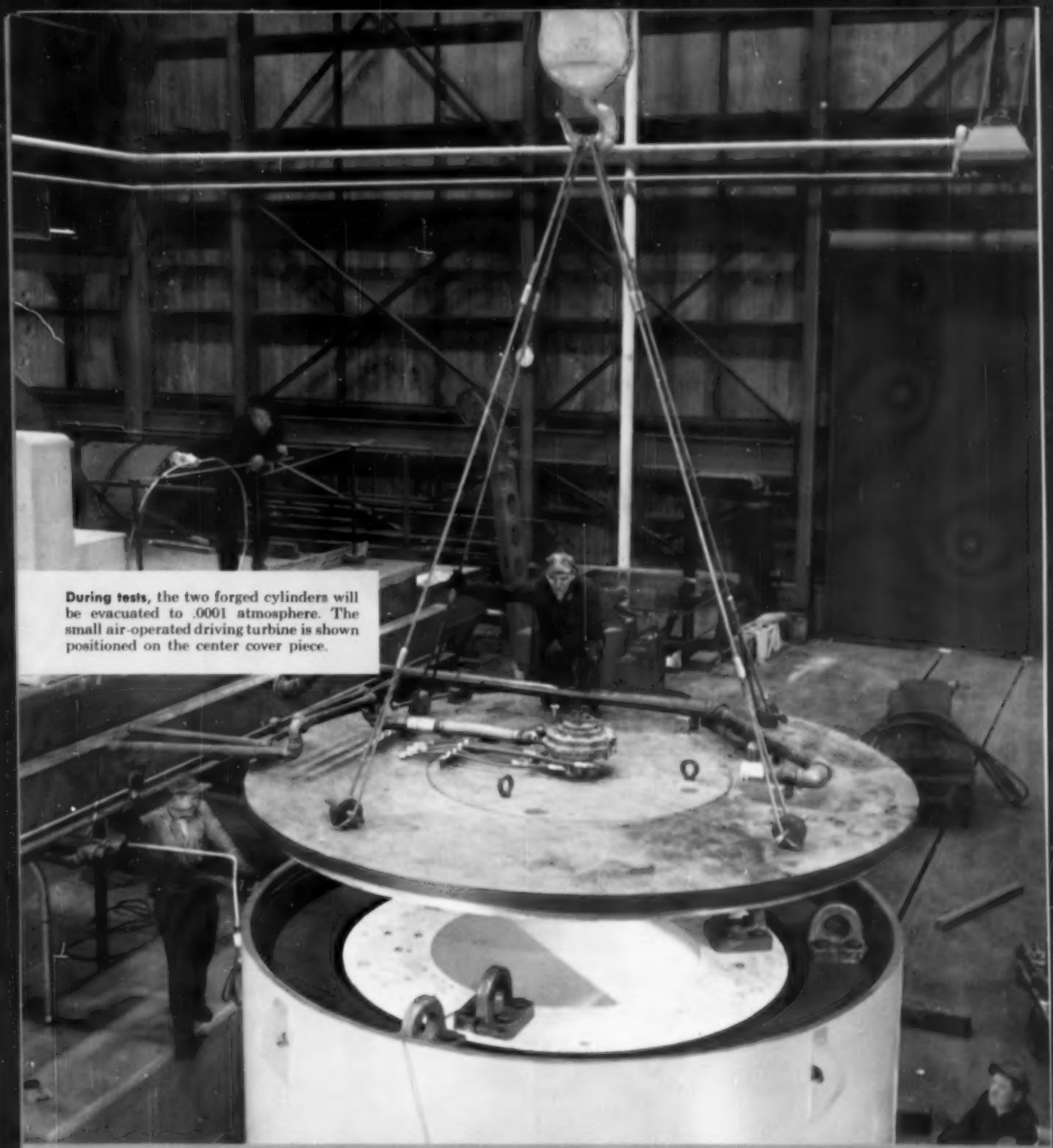
Imagine 200 automobiles traveling 100 mph crashing simultaneously. These U. S. Steel Quality Forgings have been designed to absorb that same amount of energy (200 *million* foot pounds).

With this testing facility, General Electric engineers expect to learn new things about material strength and rotor design which will permit building ever-better turbine-generator units to keep up with the demand for low-cost electric power.

U. S. Steel's Homestead Forgings Division produces a complete range of high-quality forgings, including turbine-generator shafts, heavy machinery parts, and giant sleeves like GE is using in this burst pit. We solicit your inquiries or requests for our free booklet on USS Quality Forgings. Just write to United States Steel, 525 William Penn Place, Room 4799, Pittsburgh 30, Pa.

SEE **The United States Steel Hour.** It's a full-hour TV program presented every other week by United States Steel. Consult your local newspaper for time and station.

UNITED STATES STEEL



During tests, the two forged cylinders will be evacuated to .0001 atmosphere. The small air-operated driving turbine is shown positioned on the center cover piece.

USS

Quality FORGINGS

- heavy machinery parts—carbon, alloy, stainless
- forged steel rolls and back-up roll sleeves
- electrical and water wheel shafts
- hammer bases and columns

HIGH TEMPERATURES and severe thermal shock call for furnace arches that can take it. Plant engineers find that refractory concrete furnace arches made with Lumnite calcium-aluminate cement give long, trouble-free service, yet cost less than other types.

"Now we get three forge-furnace arches for the price of one!"

NEW ARCH BEING PLACED at large midwestern forge plant. This company is enthusiastic about the outstanding service given by refractory concrete arches made with Lumnite.

FABRICATED METAL MOLDS in three sizes are used by this forge plant to cast arches for 25 of their furnaces. Refractory concrete arch sections are easily precast and stored for future use . . . eliminate costly fitting problems.

"We reduced the cost of furnace arches 65% by casting them of refractory concrete made with Lumnite* cement," reports the plant engineer of a leading forge plant in the Chicago area.** "Refractory concrete arches have given us excellent service—even in periods of extremely heavy production when temperatures soared."

Easily cast in wooden or steel molds, pre-cast monolithic arch sections save installation time by eliminating costly fitting. They give long, trouble-free service, too, because there are no small units to work loose.

You'll find many other time- and cost-saving uses for refractory concrete made with Lumnite calcium-aluminate cement and suitable aggregates in your plant. Keep a supply of Lumnite cement or prepared Lumnite-base castables on hand for emergencies. Castables are packaged mixes of Lumnite cement plus aggregates selected for specific temperature and insulation needs—made and distributed by leading manufacturers of refractories. Write today for information about industrial concretes made with Lumnite cement.

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REFRACTORY • INSULATING • OVERNIGHT • CORROSION-RESISTANT

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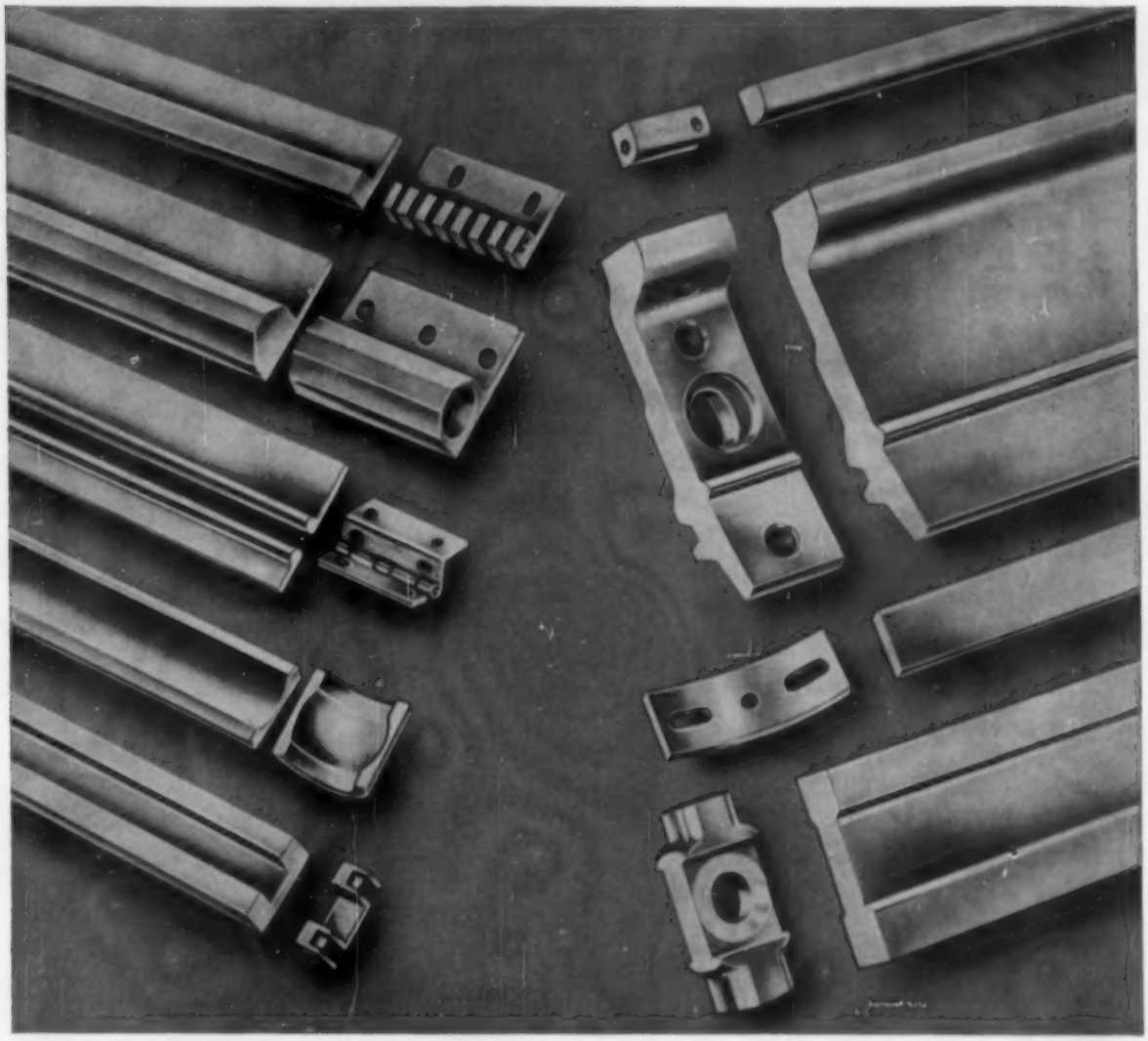

REDUCE YOUR MACHINING OPERATIONS, REDUCE SCRAP

get a superior wrought metal product with Anaconda extruded shapes

Cost-paring possibilities unlimited: In few areas can imagination and ingenuity pay off so handsomely as when applied to the use of extruded shapes. Visualize your finished parts as cross-sectional pieces cut from a long extruded shape.

Costs come down, quality goes up: Extruded metal is *wrought* metal—tough, dense-grained, smooth-surfaced, and easy to machine. When you switch from cast parts, you eliminate rejects due to pits and porosity; you reduce machining, scrap... and finishing time.

A manufacturer of hosiery knitting machines, for example, found he saved from 25-30% over cast brass. He makes 420 components from 12 different ANACONDA Extruded and Drawn Brass Shapes. He also gets the superior precision, balance, and long-wearing and bearing qualities in these parts, which must operate at high speeds.

Metals: Extruded shapes are available in copper, brass, bronze, and special copper alloys—in long mill lengths suitable for feeding into turret lathes or automatic screw machines.

Our experience at your service: The American Brass Company pioneered in extruded shapes. The accumulated experience of the organization, its wide selection of dies, may help you short-cut production and save money.

We'll be glad to make suggestions based on your sketch or sample. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

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EXTRUDED SHAPES

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X-ray inspection anywhere!

Truck-mounting of OX-175 with elevating tube stand converts this rugged, dependable, portable x-ray unit into a *mobile* inspection tool for laboratory and shop.

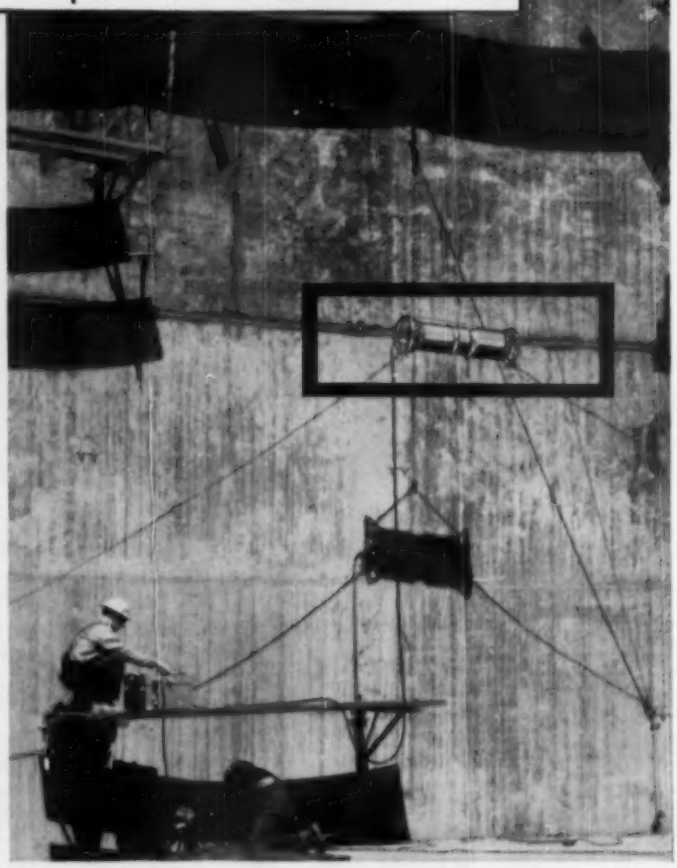
Simply staged and remotely controlled, the *portable* OX-175 provides positive check of the welds on this oil storage tank.

with industry's most versatile x-ray unit — General Electric's OX-175

Fifty feet off the ground . . . or inside a 15-inch opening — General Electric's new OX-175 is the answer to almost any radiographic inspection procedure. Light weight and small tubehead size — plus control-cable lengths up to 200 feet — permit checking of welds, castings or assemblies in the shop or in the field.

There are three models to choose from . . . any of ten types of mountings. And note this — with its flat target tube, the OX-175 produces a 360° field of radiation that can radiograph an entire circumferential weld in one exposure.

Your G-E x-ray representative will show you how the OX-175 can extend your range of x-ray inspection. Call him today, or write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, for Pub. AS124.



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NEW J & L BOOKLET ON

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WITH J&L EXTRUDED SECTIONS YOU CAN:

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3. **REDUCE** scrap losses practically to the zero point.
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J&L Extruded Sections are Custom-Made *for you*. They can be preformed to the predominating cross section of the part *you* wish to produce. And the range of sections is almost limitless. These sections possess the physical benefits and accurate tolerances derived from cold drawing. And you can obtain them in a wide range of analyses.

Use this handy coupon. This new booklet contains detailed information about the money and time saving advantages realized with the use of J&L Extruded Sections.

AT YOUR SERVICE
J&L
EXTRUDED SECTIONS
(HOT EXTRUDED AND COLD DRAWN)
. . . tailor made
to your specifications
1. YOUR section is preformed to the cross section of the part you wish to produce. The range of sections is practically unlimited.
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3. YOUR section is obtainable in a wide range of analyses . . . and, in addition, it will possess the physical benefits and accurate tolerances derived from cold drawing.
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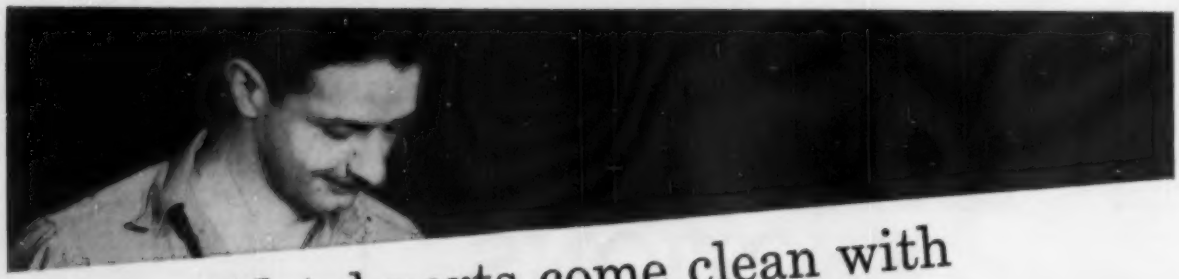

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Highest Quality • Re-usable • Economical

Photograph courtesy The Kleer-Flo Co., New York, N. Y.

NIALK TRICHLORethylene is one of the most efficient of all metal cleaning and degreasing agents.

Characterized by a high degree of purity, uniform quality and chemical stability, NIALK TRICHLORethylene is recoverable for re-use. This, coupled with its greater efficiency, makes it doubly economical . . . assuring you greater cleaning power from every gallon you buy.

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LOW TEMPERATURE SILVER BRAZING ALLOY

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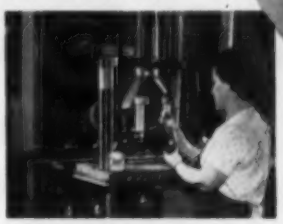
Production of the T-Flo Drier is kept at peak efficiency. Joints are brazed in an induction unit with Silvaloy preforms—a production procedure that assures positive, leakproof assemblies.

Low temperature Silver Brazing is helping to improve results, speed production and lower costs for manufacturers in many fields. Call the Silvaloy Distributor in your area for complete information or technical assistance. ★ ★ ★ ★ ★



Hex nut is Silvaloy brazed on cap which is in turn brazed to steel body. Air cylinder is used to hold spring-loaded parts in place in induction coil.

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FIELD REPORT: NO. 91

WHICH DIE STEEL WOULD YOU USE HERE to increase production from 100 to 23,000 parts?

Even after trying many different die steels, production averaged only about 100 pieces before this ring die had to be replaced.

The die cold forms cups as the first operation in producing rocket projectile noses from SAE 1010 Steel. Even though the ring die is press fitted into a four foot diameter hardened retainer ring (Rc. 34/36), the 1700 tons of pressure exerted in power extrusion prematurely stretches the die. The 12 lb. 2 oz. cups must be held within .2 of a lb. and wall thickness within .010".

Which die steel would you specify in a move to cut replacement costs and improve production?

From our customer Field Report files, here's how the toolroom solved the problem. The Carpenter Matched Set Method showed that Carpenter VEGA (Air-Tough) Die Steel was a natural for the job. Latest report shows that the VEGA ring die had increased production from 100 to 23,000 cups, and is still banging them out.

What better guarantee of success can you find for your own jobs than the word of hundreds of toolroom men who rely on Carpenter. Why settle for "ordinary" results when Carpenter is ready to help you explore the possibility for improvement? Call your nearest Carpenter Mill-Branch Warehouse, Office or Distributor now. *The Carpenter Steel Co., 133 W. Bern St., Reading, Pa.*

How can <u>your</u> toolroom use Carpenter Matched Tool and Die Steels to:

Reduce hardening hazards
Minimize machine downtime
Boost output per grind
Improve product quality

Carpenter STEEL

Matched Tool and Die Steels

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Looking for cheaper blast cleaning?

PANGBORN BLAST CLEANS CHEAPER BECAUSE famous Pangborn Rotoblast cleans *fast.* Rotoblast throws a heavy volume of abrasive quickly over a large surface area. This speed of operation increases your rate of production, cuts operating expenses.

◄ BLASTMASTER Barrel for batch cleaning

Pangborn...

Pangborn...

PANGBORN BLAST CLEANS CHEAPER BECAUSE Rotoblast actually does a terrific job! Its uniform cleaning action economically produces a more desirable, brighter finish and allows more efficient use of high-speed machine tools in further processing.

ROTOBLAST ROOM for miscellaneous work ►

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◄ ROTOBLAST "GO" Barrel for continuous-flow requirements

Whatever Pangborn Rotoblast machine best suits *your* requirements . . .

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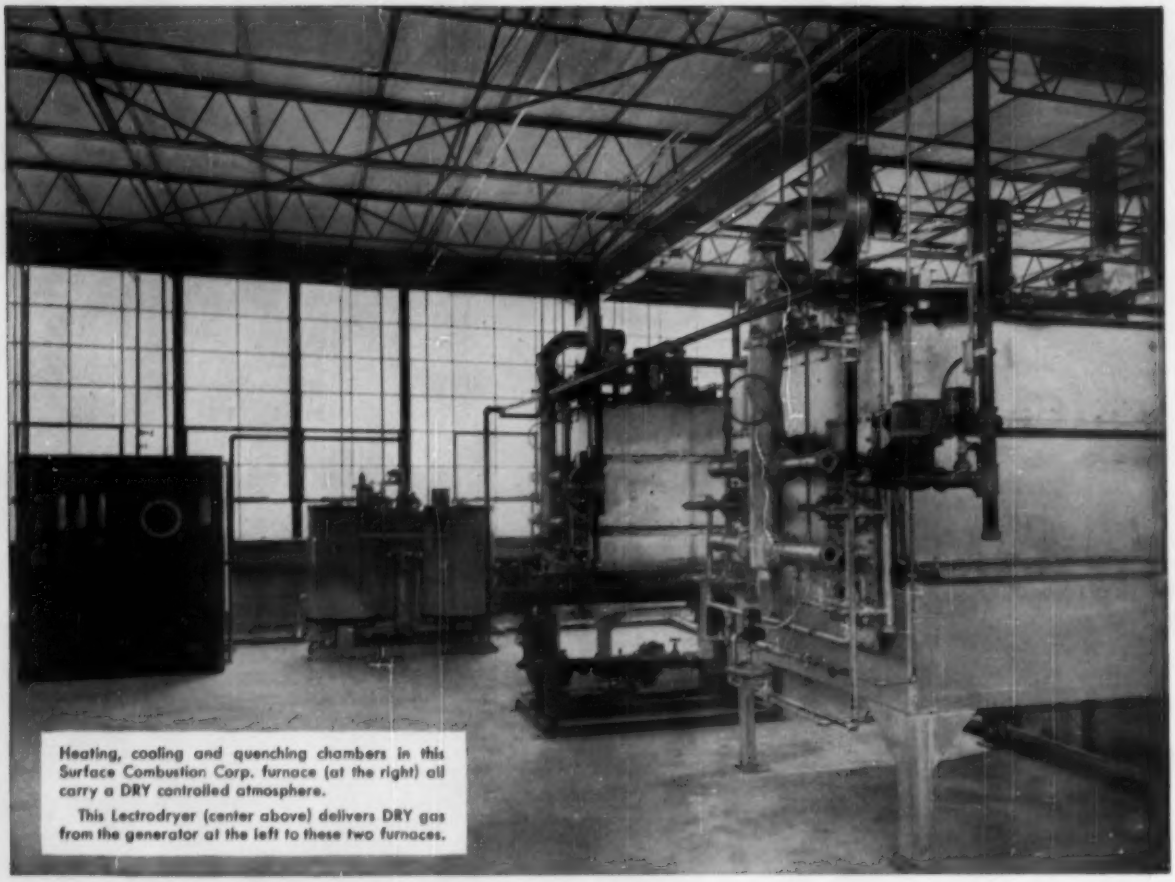
Rotoblast Blastmaster® & Continuous-Flo Barrel

Rotoblast Tables & Table-Rooms

Special Blast Rooms & Cabinets

Pangborn Dust Control Equipment

Metallobrasive® Shot & Grit



Heating, cooling and quenching chambers in this Surface Combustion Corp. furnace (at the right) all carry a DRY controlled atmosphere.

This Lectrodryer (center above) delivers DRY gas from the generator at the left to these two furnaces.

For maximum dependability, Harper Fastenings are heat-treated in a –50° F. dewpoint atmosphere

". . . plus an absolutely clean surface condition after heat treatment." That's how emphatically The H. M. Harper Company of Morton Grove, Illinois, points up the need for strict control of furnace atmospheres. Therefore, all heating, holding, slow cooling and quenching are done in special furnaces of the type shown here, to assure maximum physical properties in their high temperature and corrosion-resistant fastenings.

Extreme DRYness, a requirement for many controlled atmospheres, is achieved by this Lectrodryer*. It maintains the gas at a dewpoint below –50° F. Your gas generator or furnace manufacturer can advise you on atmospheres suited to your needs. Where DRYness is required, he'll quite likely include Lectrodryer equipment.

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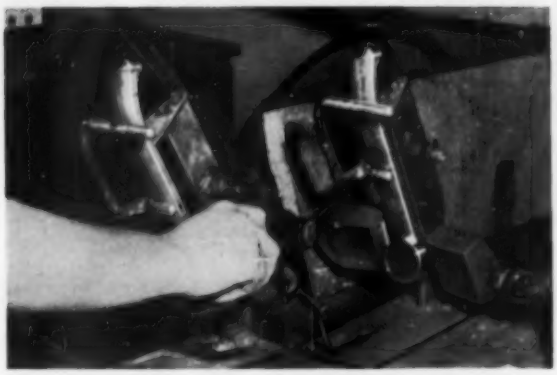

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And here's the smooth, gleaming spout after plating. No sign of a joint is visible. From every angle, it's the equal of a single, homogeneous piece.

Photos and data courtesy of the Delta Detroit Corp. Detroit, Mich.

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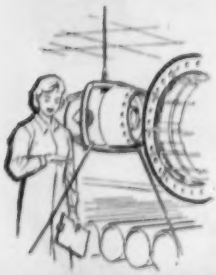

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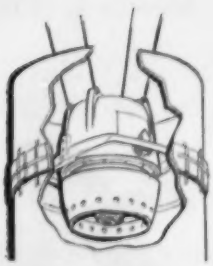

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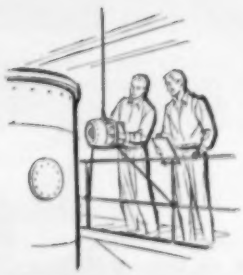

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Sheffield Tube Corporation reports: *Kemp Melting Pot melts 2,200 lbs. of lead per hour, eliminates down-time*

The Sheffield Tube Corporation, New London, Conn., manufactures tubes for toothpaste, cosmetics, drug specialties and similar products. Slugs for extruding are punched from thin lead sheets, which are rolled from moulded slabs. To melt large "pigs" for moulding these slabs, Sheffield formerly used three pots: two meltdown pots, feeding into a 1,276 lb. capacity holding pot. This equipment has been replaced by one Kemp Immersion Melting Pot, capable of melting 2,200 lbs. of lead per hour.

Kemp boosts production . . . cuts down-time

Formerly, one man produced about 500 slabs daily; dross formation had to be removed two or three times daily; and the pots were replaced after anywhere from 6 weeks to 6 months of operation. With the Kemp Melting Pot, two men now mould about 1,400 slabs daily. During the first 5 weeks of service dross was not removed once—and except for an occasional 10-minute valve-cleaning job there was no down-time at all.

Kemp can help you

Whatever your application, it will pay you to investigate Kemp Melting Pots. You'll benefit in many ways: Kemp units are not subject to periodic and expensive breakdowns . . . offer greater heating surface, faster heat recovery, lower dross formation, lower room temperatures. Whatever your problem, Kemp units will help cut labor costs, eliminate lost time, increase output.

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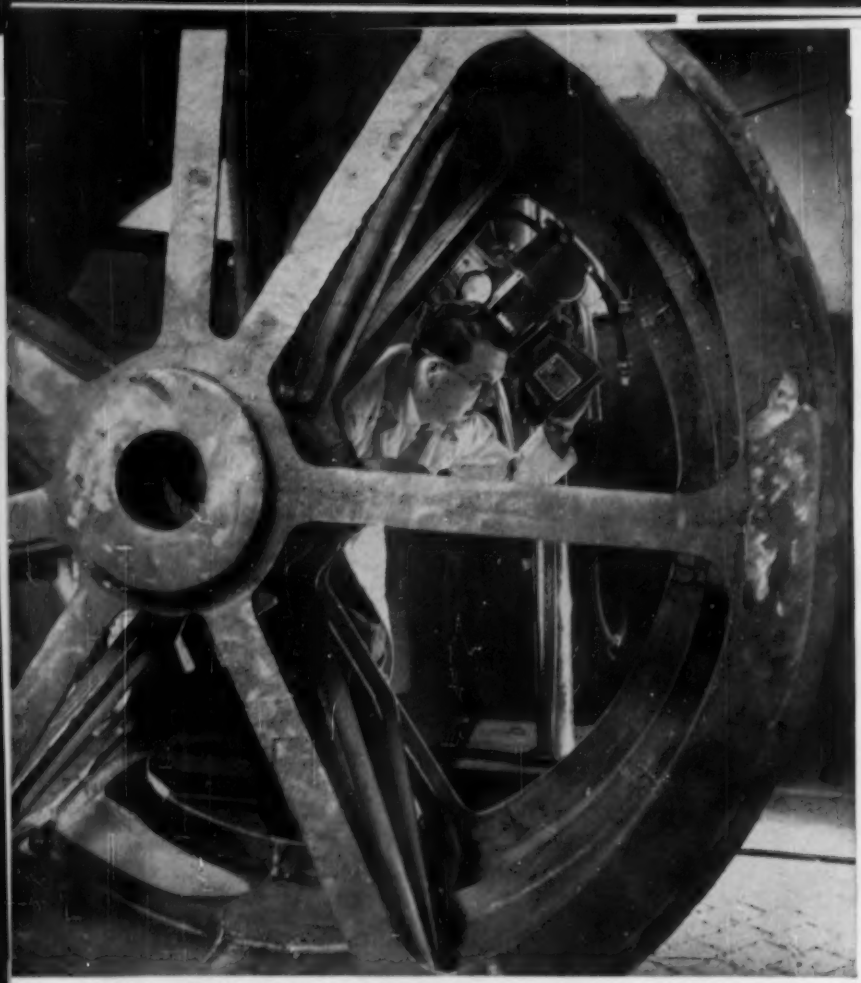

Insuring high quality is the job of the X-ray Department. Du Pont Type 506 Industrial X-ray Film is used most extensively because of its wide latitude and extreme clarity. When heavier parts are to be x-rayed, Type 504 is used with Du Pont "Patterson" Screens.

Internal characteristics of this structural casting are being checked with a 150-kv x-ray machine, using Du Pont 506 Industrial X-ray Film.

Radiographs of die castings are examined by James Bell, Val Zabek and Steve Phillips, of the Etobicoke Works, Aluminum Company of Canada.

"We've used Du Pont X-ray Film for over 12 years... its qualities are ideal for our critical work"

Val Zabek, Chief Plant Inspector, Etobicoke Works, Aluminum Company of Canada, Toronto, Ontario.

"We find Du Pont Film ideally suited for our work with light metal alloys. Du Pont Films have excellent definition, fine grain and the contrast ranges we need . . . qualities we simply *must* have to maintain critical tolerances," says Val Zabek of the Aluminum Company of Canada. "Type 506 X-ray Film is used to check products in all stages of development, insuring high quality in the final product. Our dependence on x-ray inspection means we must use a film that gives us true reproduction."

Steve Phillips, Foreman of the X-ray Department, adds: "More than 15,000 sheets of Du Pont X-ray Film are used here each month for many difficult jobs. The film is subjected to rough handling during exposure and reading. It stands up under the hard production usage we give it and has high resistance to abrasion and finger marks. It's a consistent film that we can always depend upon!"

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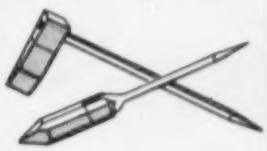

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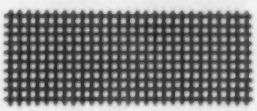

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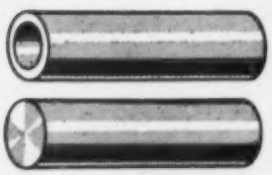

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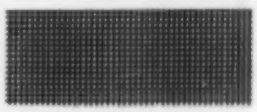

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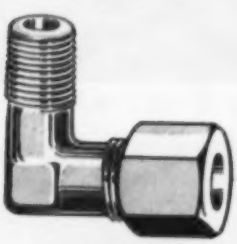

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Thompson Wire Company anneals cold rolled strip with *GAS*

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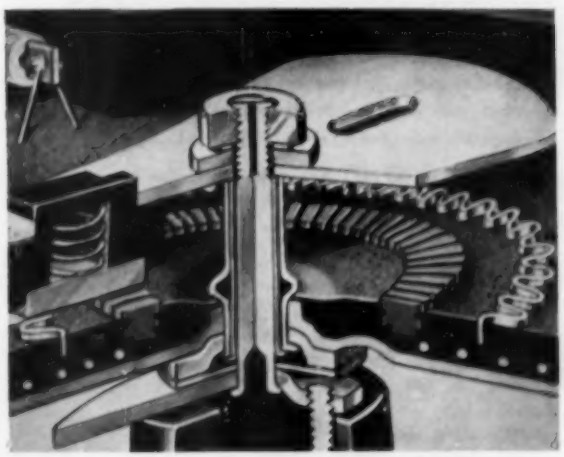
With Gas, Thompson Wire Company can anneal up to 50,000 pounds of strip in 36 hours. Thompson Wire also uses Gas for water heating.

For further information on how Gas can help you in your heat treating operations, call your Gas Company Industrial Specialist. He'll be glad to discuss the economies and results Gas and modern Gas-fired industrial equipment can provide. *American Gas Association.*

Extruded Shape Cuts Assembly Over Half

A Ward Leonard Type M Vitrohm rheostat using contacts made from extruded shapes

Ingenious application eliminates hand assembly, makes absolutely uniform stationary contacts in Ward Leonard power rheostats



CROSS SECTION VIEW of a Ward Leonard Vitrohm Type S rheostat showing how contacts are embedded in a vitreous enamel.

Ward Leonard Electric Co., Mount Vernon, N. Y., makes a line of high quality power rheostats marketed under the trade-name Vitrohm. Anywhere from 41 to 161 individual stationary contacts, or buttons, have to be embedded with their resistance elements in an insulating vitreous enamel—all contacts uniformly set and spaced, for uniform performance. Their patented process originally used buttons blanked out of sheet brass—hand assembled and spaced on a steel wire to hold them while the vitreous enamel was fired.

Ward Leonard refined the process and for four models now starts with the extruded shapes shown above. The stock is accurately slotted for correct spacing, forming a continuous line of buttons connected by a triangular "wire"—which is an integral part of the extruded shape. When sections are curved, the buttons remain uniformly spaced and oriented. After the button assemblies are embedded in the vitreous enamel, the connecting wire is easily milled off. Ward Leonard gets absolute uniformity with less effort and fewer rejects—it gets healthy dollar savings, despite the fact that more than half of the extruded shape is milled out.

Imagination applied to extruded shapes can pay big dividends—lower direct labor costs—fewer machining operations—less scrap—improved product quality. Your Anaconda representative will be glad to work with you. The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 5504

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The secret of Rycut's machining speed is a minute quantity of lead, finely dispersed throughout the steel. This acts as a lubricant between tool and steel. The results are revolutionizing machine shop practice:

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There's a Rycut leaded alloy for every application. Use RYCUT 20 when you need a carburizing alloy; RYCUT 40 for .40 carbon alloy applications; and RYCUT 50 for .50 carbon alloy uses. Every one is a cost-cutter.

Figure how much this increased production and longer tool life would lower costs in YOUR shop—and raise your profits! Call your nearby Ryerson plant today . . . large stocks assure you of quick shipment.

NOW LEADED PLATES—Ryerson's New E-Z-Cut is the first leaded plate steel available from stock. It cuts faster, polishes easier than other free-machining plate steel.

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Metal Progress
Volume 68, No. 6 December 1955

Metallurgical Problems in Design of Nuclear Power Reactors

*By VINCENT P. CALKINS**

Selection of materials for use in nuclear reactors is limited by such factors as radiation change and neutron absorption characteristics in addition to the usual engineering considerations. Often, powder metallurgy is the only way to fabricate the uncommon metals which have the properties required. (T 25)

ATOMIC FISSION is a new source of energy which may well compete with water power and combustion processes, for in many ways it is more versatile than either of these two prime energy sources. Unlike water power, nuclear power can be generated in lands devoid of natural water power resources. Unlike coal, gasoline, oil and gas, nuclear power can be used without continually transporting tons upon tons of fuel material. Once a nuclear power plant is established, only relatively small amounts of nuclear fuel need be transported at infrequent intervals for continuous power production.

Although nuclear power is more versatile, the over-all power plant is similar to that for combustion processes. There are two essential parts – a controlled nuclear heat source, and a heat engine. The nuclear heat source is equivalent to a combustion chamber, and the engine can be a steam turbine or other conventional type of heat engine, perhaps somewhat modified. The modification of any conventional heat engine might involve various metallurgical problems,

*Supervisor, Materials Research and Radiation Studies, Aircraft Nuclear Propulsion Dept., General Electric Co., Cincinnati, Ohio. Condensation of paper presented before meeting on "Powder Metallurgy in Atomic Energy", jointly sponsored by U.S. Atomic Energy Commission and American Society for Metals during the National Metal Congress in Philadelphia, Oct. 20, 1955.

but the real difficulties arise in design of a controlled nuclear heat source or "power reactor".

In general, a nuclear power reactor consists of the following components:

1. A nuclear fuel in a liquid or solid matrix material. In fissioning the fuel gives up a considerable portion of its fission energy in the form of heat, and the matrix material serves as a fuel vehicle or support.

2. A moderator to slow down the fast neutrons so that they can more readily be captured by certain isotopes in the nuclear fuel and thus sustain the fissioning.

3. A reflector to scatter back some of the neutrons which are leaking or escaping from the vicinity of the nuclear fuel.

4. A control material containing a high neutron absorber, such as boron, to control fissioning by regulating the surrounding neutron density.

5. A coolant (gaseous or liquid) or heat transfer medium to remove the fission energy to the heat engine.

6. A shield consisting of various materials to reduce the extraneous neutron and gamma radiation to a human tolerance level outside the machine.

7. Structural materials of requisite strength under the existing temperature and stress.

General Metallurgical Problems

At this point, it would be well to ask and to answer the question, "What are some of the general metallurgical problems involved in the design of a nuclear power reactor?" Certainly, it is safe to say that each of the reactor components will present problems which will interest even the most discriminating metallurgist. Although they may be classified in various ways we shall broadly classify all of them as a function of the following four factors: *(a)* physical and mechanical property requirements, *(b)* nuclear property requirements, *(c)* corrosion limitations, and *(d)* radiation damage.

Physical and Mechanical Property Requirements – There is one outstanding difference between the physical and mechanical property requirements for conventional power units and nuclear power reactors. In a conventional unit the construction materials of the combustion chamber are heated externally. In a nuclear power reactor, the heat is liberated internally in the nuclear fuel (usually a solid) and spreads from the inside, out through the fuel matrix and through the cladding or container material to the coolant stream. This nuclear heat must pass to the coolant stream at an efficient rate or the entire containing system will simply melt and vaporize, for the heat produced by fission is virtually independent of the temperature of the nuclear fuel or its environment. Therefore, it is necessary that fuel-matrix materials have a very high thermal conductivity and that a good heat transfer surface exist between the fuel matrix and the container material. With clad fuel elements, a sound metallurgical bond must exist between the fuel matrix and the cladding. For liquid fuel vehicles, the liquid must wet the internal surface of the container. Even with materials that have high thermal conductivities and sound mechanical bonds, large temperature gradients exist. These temperature gradients, from the inside to the outside, increase the normal stress problems and act as stress concentrators which can cause premature failure.

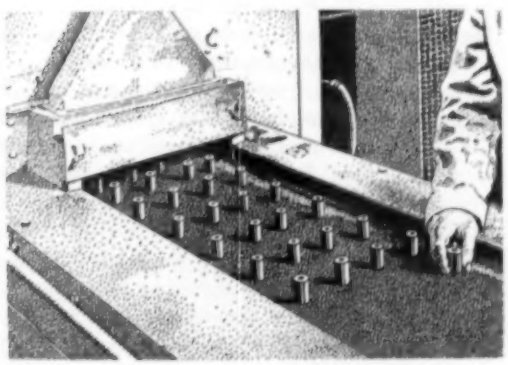
Nuclear Property Requirements – For components near the nuclear fuel – the fuel matrix, moderator, core structure, reflector, coolant materials and the associated piping and structure – materials must be chosen which absorb a minimum of the free neutrons so that the reaction may be maintained without an excessive amount of nuclear fuel. Materials in the control rods must have even higher thermal neutron absorption cross sections than the fuel so that the reactor can be controlled properly. For those components of a nuclear power reactor such as a recirculating coolant, which are normally in a high radiation field but are frequently removed from the reactor, materials with low thermal neutron absorption cross sections are desired, since the induced radioactivity due to the secondary radiation can constitute a real physiological hazard as well as a mechanical handling problem. For shielding materials used to protect removable components or accessible portions of the reactor from induced activity, a high thermal neutron absorption cross section is obviously desirable. In general, the thermal neutron absorption cross section is probably the most important single property of a nuclear power reactor material.

Corrosion Limitations – Corrosion resistance in nuclear reactors is more important in at least two respects than for conventional units. Whether the coolant is a liquid or a gas, the nuclear fuel in the matrix material must be protected by cladding or by a container so that highly radioactive fission fragments do not contaminate the coolant stream. For clad fuel elements, the temperature along the cladding may vary considerably because of uneven heat transfer; these

temperature gradients can cause accelerated corrosion of the cladding by the coolant.

Radiation damage can be defined as any adverse change in the physical and chemical properties of a material as a result of exposure to radiation. Studies in this field are being continually pursued throughout the country, to the limits imposed by existing reactors especially built for testing materials, and observations gained by maintenance or demolition of reactors for other purposes. In brief, radiation damage to organics and other covalent materials occurs primarily as a result of molecular excitation and ionization of the material; the resulting damage is independent of the type of radiation particle, but it is directly dependent upon the amount of energy absorbed or deposited. In other words, equivalent damage to organic materials is obtained for equivalent energy absorption, regardless of the type of radiation or the dose rate; this is a rule of thumb and is valid at least within a factor of two. For inorganics and metals, radiation damage occurs not by molecular excitation and ionization but primarily by dislocations of atoms within the crystal lattice induced by radioactive particle bombardment. This phenomenon in the fuel and fuel matrix material is due to the creation of fission fragments from the original atoms of the nuclear fuel isotope, and in other metallic parts of the reactor to collisions with the fast neutrons emitted by fission. In general, organics are over a thousandfold more susceptible to radiation damage than inorganic and metallic materials.

Now that we have briefly presented the very broad physical, mechanical, nuclear, corrosion and radiation damage aspects of a nuclear power reactor, let us give in slightly more detail some of the general metallurgical problems associated with several of its components, namely, fuel matrix, moderator, and control components.



Fuel Matrix – Either liquid or solid fuel systems can be used in a nuclear power reactor, but since many of the reactor designs presented in the open literature by commercial organizations are based upon a solid fuel, we shall limit our discussion to this system. The fuel elements, therefore, are required in solid forms which may be of various shapes and compositions. Two nuclear fuels available for these elements are uranium and thorium. Both are metals for which there existed no technology of any importance 15 years ago. The metallurgist has had to devise means of preparing the metals, fabricating them in useful form and of establishing the physical, chemical and mechanical properties which govern their use. The metallurgy of both materials is complicated by their highly reactive nature, and corrosion is always a serious problem. Moreover, both metals, while possessing excellent strength at room temperature, are very weak and ductile at elevated temperatures (above 1500° F.). The metallurgical problems, therefore, in the use of uranium and thorium for fuel elements are *(a)* fabrication into useful shapes, *(b)* protection from corrosion by cooling media, and *(c)* providing mechanical stability at high temperature. The properties of uranium for fuel elements may be improved somewhat by alloying to give improved strength or corrosion resistance, and the metallurgist must develop means of preparing such alloys – not always a simple problem. Perhaps because of technical or economic reasons, it may be desirable to use uranium in the form of a chemical compound such as the oxide rather than as the metal or its alloys. The advantage of this type of fuel element is that by incorporating the uranium as a nonreactive compound within the metallic matrix of a corrosion resistant high-strength alloy, the chemical and physical properties of the fuel element are essentially those of the sheath material.

Moderators – For the moderation of power reactors, one is generally limited to water, carbon, beryllium or their compounds. Water is the most useful since it is the cheapest and yet one of the most effective moderators. However, even the use of water involves various metallurgical problems, especially relating to corrosion, pressure and temperature, since it must be contained in high-pressure systems and used at temperatures considerably above its normal boiling point. The use of other liquid hydrogenous materials also involves difficult container problems. Solid moderators such as beryllium, carbon or compounds of these elements present problems asso-

ciated with fabrication and use. Dissipation of moderator heat and corrosion by coolants are problems of interest.

Control Components – Control of reactors requires the use of high neutron absorbers such as boron, cadmium and the rare earths. None of these materials can be classed as high-strength structural metals, and boron, in fact, may be considered more nonmetallic than metallic. The problem of the metallurgist is to incorporate these neutron poisons into fabricated bodies which possess adequate chemical and mechanical stability for service. Except for cadmium, the metallurgy of these elements has received relatively little attention to date. Much remains to be learned since boron or boron compounds – the most effective and readily available of the control element materials – do not form structural alloys in the usual sense of the word. There is a real need for metallurgical processes for forming structural bodies containing boron or other high neutron absorbing compounds.

Role of Powder Metallurgy

In comparing the two general methods used for consolidating metallic bodies (melting and casting versus powder metallurgy techniques), we note first that the temperatures for consolidating powders are considerably lower. Thus, if tungsten – a possible shielding material – were to be consolidated by melting and casting, it would have to be heated to temperatures above 3400° C. (6150° F.). By powder metallurgy, useful tungsten alloys and bodies near theoretical densities may be obtained by sintering at temperatures as low as 1600° C. (2910° F.). Furthermore, in the powder metallurgy technique, although support must be provided for the work during processing, the container problems are not nearly so serious as those associated with highly reactive liquid metals.

In some of the more complicated alloys, solidification occurs over a wide temperature range, and segregation may be so extensive that the properties of the elements are determined by the properties of the last material to solidify. In some systems, solidification is accompanied by considerable column contraction of the metal. As a result it is difficult to obtain sound bodies. Last but not least, although fine-grained materials may be obtained by rapid cooling through the solidification range, very large grain structure will generally result from melting and casting processes.

In comparing sintered bodies with cast structures, it is frequently assumed that sintered metals are more prone to cracking when worked. This is not necessarily true. Because of segregation within cast structures and large grain size, it is sometimes more difficult to break down such cast structures without subsequent cracking than the equivalent fine-grained powder metallurgy material. There are, thus, very definite advantages for the powder metallurgy product.

Specific Applications – The use of powder metallurgy to fabricate components of a nuclear power reactor is extremely important. It allows the metallurgist to consolidate sound bodies even though the constituents may be highly reactive in the liquid state. For example, a nuclear fuel such as uranium oxide can be incorporated in a metallic matrix, and the whole thing clad to produce a custom-made high-strength fuel element. Materials such as carbon or beryllium oxide can be pressed to near theoretical density in the size and shape desired for a good, sound moderator body. A nuclear poison such as boron can be incorporated in metal matrices by powder metallurgy, to form a highly efficient reactor control body. All these powder metal fuel elements, moderators and controls can be wholly stable over useful temperature ranges even though the metals themselves may be thermodynamically unstable and lose all their desirable properties if heated to the temperatures required for melting and casting.

Conclusions

Materials such as aluminum, magnesium, copper, iron and nickel, which are the basis for our present conventional power plant technology, cannot answer all the metallurgical problems associated with the design and development of nuclear power reactors. The entire metallurgy of all metals and alloys must be drawn upon for the proper rearing of this new and exciting infant of industry. The potential contribution of powder metallurgy to this field should not be hard to understand for anyone who is familiar with metallurgical processes and techniques. In some instances, the justification of powder metallurgy may be simply that of economics – just the fact that it may be cheaper to stamp out a simple gear from an iron-base alloy by powder metallurgy than to machine it from bar stock. Cost, however, is generally not the prime reason. Powder metallurgy in the nuclear power reactor field is of prime importance because in many applications it is the *only* way we know to fabricate materials in the forms desired.

Preparation of Metal Powders for Nuclear Reactors

*By P. CHIOTTI and H. A. WILHELM**

Both uranium and thorium powder may be prepared by forming the hydride and decomposing it by heating under reduced pressure. (H 10, U, Th)

In the development of nuclear power reactors many problems arise for which powder metallurgy techniques offer certain advantages over conventional metallurgical procedures. Consequently, procedures for preparing high-purity powders of such metals as uranium, thorium, beryllium and zirconium are important.

The method suitable for a particular metal depends on the physical and chemical properties of the metal and the reactivity of the metal powder. In general, the preparation of metal powders might be divided into two classifications, *(a)* physical methods by which massive metal is converted into a powder by crushing, grinding, milling, machining or atomizing, and *(b)* chemical methods whereby the metal powder is obtained by chemical or electrolytic reduction or by the thermal decomposition of volatile compounds. A few methods involve both chemical and physical means such as in the crushing of metal which has been embrittled by treatment with hydrogen.

Preparation of Uranium Powder

Most of the methods for the preparation of uranium metal yield the metal in powder form. In general, they involve the reduction of uranium oxides with calcium, magnesium or calcium hydride; the reduction of uranium halides with potassium, sodium, magnesium, or calcium; or the electrodeposition from fused salts.

The method used to prepare quantities of metal for the Manhattan Project prior to the end of 1943 was the electrolysis of KUF_5 in a fused $NaCl\text{-}CaCl_2$ bath. The powder obtained had as much as 99.9% uranium, the impurities being principally iron, carbon and silicon.

High-purity uranium in massive form has been produced by the reduction of uranium tetrafluoride with either calcium or magnesium. The procedure using magnesium is described in detail in an article that will appear in the February issue of *Metal Progress*. Granulated magnesium mixed with uranium tetrafluoride is packed inside a steel bomb which is lined with a jolt-packed dolomitic oxide powder. The reaction may be initiated by heating the bomb in a gas-fired furnace. It proceeds rapidly to completion, and since it is exothermic, the metal and slag separate as two liquid layers. After cooling to room temperature the "biscuit" of metal produced can be easily cleaned of any adhering slag.

This method for preparing uranium metal has a number of desirable features. The tetrafluoride, which is readily prepared by hydrofluorination of the dioxide, is stable, nonhygroscopic and can be handled in air without any special precautions. High-purity magnesium is commercially available and relatively inexpensive. High yields are obtained and the purity of the final product is determined primarily by the purity of the starting materials. The massive metal is stable and easily stored, and is readily converted to metal powder by the formation and decomposition of the hydride.

Hydride Process – Uranium reacts with hydrogen to form the hydride UH_3 which has two

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allotropic forms. The usual form obtained by reaction of the metal with hydrogen at 480° F. has a cubic lattice with eight uranium atoms per unit cell. Its specific gravity is 10.83. Another crystalline modification is produced simultaneously when the reaction is carried out at lower temperatures. This allotropic form is also cubic but has two uranium atoms per unit cell and a specific gravity of 11.03. When the mixture of the two forms is heated at 480° F. for 100 hr. the denser form is transformed to the lighter modification. The transition does not appear to be reversible on cooling and the high-temperature form exists unchanged for long periods of time at room temperature.

The optimum temperature for the formation of the hydride is 430° F. The reaction rate drops rapidly as the temperature drops below 390° F. or goes above 480° F. Traces of impurities in the hydrogen or an oxide film on the metal result in an induction period during which the reaction is very slow. Once the reaction is under way it proceeds smoothly. At 480° F. a charge of 100 g. of clean uranium shavings is completely converted to the hydride in about a half hour; a massive piece of metal of the same weight requires 1½ to 2 hr. The product is a finely divided and highly pyrophoric powder. The large difference in density between the metal (19.0 g. per cc.) and the hydride (10.8), and the brittle nature of the hydride are probably the most important factors contributing to the formation of a finely divided powder.

The hydride is readily decomposed by heating under reduced pressure. If the decomposition is carried out at 570 to 750° F. a slightly sintered metal powder is obtained which can be broken up to give a metal powder with an average particle size of 3 to 10 microns.

The preparation of uranium powder by this procedure is simple, and suitable apparatus is available in most laboratories. The reaction can be carried out in a quartz tube. A mercury manometer, vacuum pump, a purification train for the hydrogen, and a resistance furnace for heating the charge are all the additional equipment necessary. The metal, either as massive chunks, turnings or chips, is usually coated with a thin film of oxide which should be removed prior to the formation of the hydride. The oxide can be removed with 1:1 nitric acid. (Higher acid concentration can lead to violent reaction with uranium.) The hydride can be formed and decomposed in the same reaction tube, thus eliminating the necessity of handling the pyrophoric hydride. However, pure uranium powder is also pyrophoric, and handling the powder without contaminating it with oxide, nitride or other impurities is not a simple problem. Consequently, the apparatus should be constructed so that the reaction tube can be closed off from the rest of the system and then detached and transferred to a dry box where it can be unloaded under an inert atmosphere. Once the metal powder has been pressed into a compact, it can be handled in air at ordinary temperatures without spontaneous ignition.

Preparation of Thorium Powder

The problems involved in the preparation of thorium powder are similar to those in the preparation of uranium powder. As with uranium, most of the older methods yield the metal in powder form. The product is usually an agglomerate mass, consisting of reaction products or unreduced salts, which can be crushed and leached to yield a metal powder. Metal powder of good quality has been produced by the reduction of the oxide with calcium, the reduction of thorium halides with calcium, magnesium, and alkali metals and by the electrolysis of fused salts.

Fused Salt Electrolysis – Thorium powder has been prepared by the electrolysis of $KThF_5$ in a fused salt bath consisting of equal weights of NaCl and KCl. The electrolysis was carried out at 1380 to 1430° F. in a graphite crucible which served as anode. The thorium was collected on a molybdenum cathode at a current density of 90 amp. per square decimeter. It consisted of a mixture of coarse powder along with very finely divided powder.

Some of the factors influencing the particle size of metal powders produced by fused salt electrolysis are the temperature, current density and bath composition. The crystal size of the deposit is decreased as the current density is increased and also as the impurity content of the bath is increased. These characteristics are believed to be due to the formation of alkali metal film on the cathode surface and polarization effects. Polarization is more pronounced at low temperatures.

Reduction of Thorium Halides – Metal powder of good quality has also been produced by the reduction of thorium halides with calcium, magnesium or sodium. The powder obtained is usually less than 100 mesh (0.149 mm.), but presumably can be made coarser or finer than this depending on the final reaction temperature

and other experimental conditions. The major impurities are usually oxygen, nitrogen, hydrogen and carbon. The amount of oxygen, hydrogen and nitrogen can be reduced by melting the metal under high vacuum.

The processes employing the tetrachloride usually yield the metal in a finely divided state. Thorium tetrachloride is volatile and hygroscopic. The tendency of this salt to be contaminated with ThO_2 or $ThOCl_2$ usually results in metal powder with a high oxide content. However, vacuum sublimation can be used to purify the chloride. If calcium is used as the reductant, the oxide-containing compounds are of little concern since they are reduced to give calcium oxide which can be removed by the usual leaching procedures.

The magnesium reduction of the tetrachloride offers certain advantages over the use of calcium for large-scale production of metal. Magnesium is obtainable in higher purity and lower cost per pound than calcium. Due to its lower atomic weight less magnesium is required per pound or thorium produced than the weight of calcium required. Magnesium forms a low-melting alloy with thorium and under proper conditions the reduction process can be made to yield a liquid alloy. The magnesium can then be removed by distillation and the thorium metal is obtained in the form of a sponge. Complicated leaching procedures are eliminated and the thorium sponge can be converted to metal powder by the hydride process.

A process for the production of thorium metal by the calcium reduction of ThF_4 has been operated on a tonnage scale by the U.S. Atomic Energy Commission. Metal was prepared by this process at Iowa State College where the process was developed and operated for a number of years. The ThF_4 was obtained by precipitation of thorium oxalate from a solution of purified thorium nitrate, followed by calcination of the oxalate to oxide and then hydrofluorination of the oxide to ThF_4.

The metal is first obtained as a massive Th-Zn alloy. In addition to the ThF_4 and the calcium metal, the charge contains anhydrous zinc chloride. The primary reaction products are thorium metal, calcium fluoride, zinc metal and calcium chloride. The addition of anhydrous zinc chloride to the charge serves to promote the separation of thorium from the slag in three ways: *(a)* The zinc alloys with the thorium to give a low-melting metal phase, *(b)* the calcium chloride fluxes the calcium fluoride slag, and *(c)* the heat of the auxiliary reaction between $ZnCl_2$ and calcium serves as a thermal booster and raises the temperature reached by the reaction mixture. As a result, the products of the reaction reach a temperature at which they are molten, and the metal and slag phases readily separate and subsequently solidify in position on cooling. Because of the high vapor pressure of zinc at reaction temperatures, it is necessary to carry out the reaction in a closed pressure vessel or bomb, lined with a refractory material such as calcium oxide or dolomitic oxide. After the charge is introduced and covered with a layer of dolomitic oxide or calcium oxide, the bomb is closed with a steel lid and the assembly then placed in a furnace to ignite the charge.

After the products are cool, the bomb is opened and the massive metal piece, or "biscuit", is cleaned of adhering slag. The biscuit is heated in a vacuum to remove the zinc, leaving thorium metal sponge. A charge containing about 275 lb. of sponge and croppings is then vacuum-melted by induction in a beryllia crucible and bottom-poured into a graphite mold of the desired shape.

Hydride Process for Thorium Powder — Thorium in the form of sponge, massive metal, chips or lathe turnings can be converted to metal powder by the formation and decomposition of the hydrides. There are two compounds of thorium and hydrogen — one with the formula ThH_2, and a higher hydride, Th_4H_{15}.

The procedure for preparing thorium powder from massive metal can be broken down into the following steps:

1. Formation of the dihydride, ThH_2, at 1110 to 1200° F. at one atmosphere hydrogen pressure. During this step the charge swells but does not break up into a powder.

2. Formation of the higher hydride at temperatures not above 610° F., preferably about 480° F. The charge exfoliates and breaks up into a coarse powder during this operation.

3. Decomposition of the higher hydride by heating to 930° F. under a pressure of one atmosphere of hydrogen.

4. Decomposition of the lower hydride at 1290° F. at low pressure.

For the preparation of small lots of powder these steps can be carried out in a fused silica tube. However, if 10 lb. or more of powder is to be produced, a steel (preferably stainless) reaction chamber is more suitable. The remainder of the equipment consists of a mechanical vacuum pump, a diffusion pump, a suitable

vacuum gage for measuring low pressures and a mercury manometer for measuring pressures near one atmosphere. It is possible to check the reaction rate by temporarily closing off the hydrogen supply and observing the rate of pressure drop. A purification train for the hydrogen and a liquid nitrogen trap to prevent diffusion of oil vapors from the vacuum pumps to the charge should be included.

A charge of lathe turnings or chips is preferable since the time required to form the hydride depends on the surface-to-mass ratio of the charge. A 10-lb. charge of shavings or chips can be converted to metal powder in 8 to 12 hr. Large pieces of massive metal weighing 4 to 5 lb. have also been successfully converted to metal powder by this process. The formation of both the dihydride and the higher hydride is exothermic. With a charge of shavings, chips, or sponge the formation of the dihydride is sufficiently rapid and exothermic to bring the charge to a red heat, and no heating is necessary once the reaction starts. With large massive pieces of metal, the reaction is not sufficiently rapid to maintain the optimum temperature.

The higher hydride is decomposed simply by heating to 930° F. in hydrogen. The lower hydride is decomposed by heating at 1290° F. under vacuum. The thorium powder obtained by this process is rather coarse but can be easily broken up to pass a 30-mesh screen.

Finer powder may be produced by breaking up the brittle hydride by ball milling under an inert atmosphere and then decomposing the hydride. The plasticity of the metal particles obtained depends to a considerable degree upon the purity of the original metal and the residual hydrogen content. If the system is pumped down to a pressure of less than 0.5 mm. Hg at 1290° F. the powder produced from high-purity cast metal is soft and plastic, and is readily fabricated into ductile shapes.

Reactivity of Powders

Coarse granular thorium powder can be handled in air at room temperature without spontaneous ignition. However, freshly prepared powder, or powder which has been freed of surface adsorbed gases can ignite spontaneously when suddenly exposed to air. The initial rate of gas adsorption is apparently sufficiently rapid and exothermic to raise fine particles to the ignition temperature. Highly polished massive metal is also observed to tarnish slowly on exposure to air. Consequently, fine thorium powder with a large surface-to-mass ratio is likely to be contaminated with appreciable amounts of oxygen and possibly nitrogen after exposure to air. Adsorbed oxygen cannot be removed by heating under high vacuum. Adsorbed nitrogen is believed to behave similarly at temperatures below the melting point of the metal.

Uranium and the hydrides of both thorium and uranium in the form of finely divided powders ignite spontaneously on exposure to air. Thorium powder does not appear to be as sensitive as uranium powder in this respect. However, freshly prepared thorium powder can ignite spontaneously at room temperature when suddenly exposed to air. The tendency toward ignition will depend of course on the particle size of the powders concerned. Once any of these powders are ignited they burn rapidly at a white heat. The usual fire extinguishing agents such as water, carbon tetrachloride, or carbon dioxide are ineffective since the powders will react with them at high temperatures. Fires involving small amounts of powder can be controlled to some extent by covering the powder with a heavy layer of anhydrous CaO or MgO powder. Undisturbed layers of uranium, uranium hydride and thorium hydride ignite within a few minutes after exposure to air at room temperature. Similar layers of thorium powder ignite at 540° F. Layers of these powders also ignite in carbon dioxide and nitrogen atmospheres at temperatures in the range of 410 to 930° F.

Dust clouds of these powders can explode violently. Uranium and uranium hydride dust ignite at room temperature immediately upon dispersion in air, while thorium and thorium hydride dust ignite at about 500° F. Dust clouds of thorium, uranium and uranium hydride ignite in carbon dioxide at 1360, 1040 and 1330° F. respectively. They do not ignite in a nitrogen atmosphere at temperatures up to 1560° F. The minimum concentration for explosive air-dust mixtures of these powders ranges from 0.06 to 0.08 oz. per cu. ft. It is advisable to handle and process them under helium or argon gas.*

Care should also be taken to avoid inhalation or ingestion of these powders. These metals are not highly toxic chemically, but their decay products and the associated radioactivity can be dangerous to health.

*Data on dust explosions from work done by I. Hartmann, J. Nagy and M. Jacobson, "Explosive Characteristics of Titanium, Zirconium, Thorium, Uranium and Their Hydrides", Bureau of Mines Report of Investigations 4835, December 1951.

Fabrication of Zirconium by Powder Metallurgy Techniques

By HAROLD H. HIRSCH*

Full-density ductile parts are achieved by pressing zirconium hydride powder and vacuum sintering at moderate temperatures. Canned billets can also be readily rolled or extruded. (H general, Zr)

ZIRCONIUM and beryllium belong to a small group of metals that possess a low affinity for the nuclear blood of an atomic reactor, the neutron. This affinity is generally called the neutron capture or absorption cross section; it varies with the speed at which the neutron is traveling. In Table I, the relative absorption cross sections of the common metals and other pertinent elements for neutrons possessing thermal energies (in thermal equilibrium with their surroundings) are compared on the basis of beryllium equal to one. Although zirconium has a cross section 20 times that of beryllium and three times that of magnesium, it possesses mechanical and corrosion properties that make it attractive for many nuclear applications. Within limits it can resist attack by coolants used in various reactors, such as hot water, liquid sodium and several gases. It has more ductility than beryllium, and may be used for structural parts in the reactor and as a protective cladding and diluent or dispersant for the fissionable fuel. It will be considered at some length in this paper, to the exclusion of beryllium, because the "Fabrication of Beryllium by Powder Metallurgy" was described in a paper by Wallace W. Beaver in *Metal Progress* in April 1954, and many other aspects of the metal are considered exhaustively in the recent ⓐ book "The Metal Beryllium".

Zirconium – although the first pieces of ductile zirconium were produced as early as 1914, extensive effort on quality and quantity production awaited the American atomic energy program after the second world war. The need was for ductile, high-purity metal and methods for consolidating and fabricating it into desired shapes. Two processes evolved, *(a)* the so-called Van Arkel process which produces a crystal bar by the decomposition of zirconium tetra-iodide on a heated filament and *(b)* the Kroll process which produces a zirconium sponge by reducing the tetrachloride with magnesium. The crystal bar zirconium is somewhat purer, but much more costly; hence the Kroll process is in greatest use.

Either product had to be worked into dense, usable shapes and this proved to be as difficult a problem as producing the pure metal. No crucible could be found that would not react with molten zirconium. The current practice is to melt crystal bar or sponge zirconium by inert arc into a water-cooled mold. The search for a more adaptable and possibly cheaper technique has led to the investigation of powder metallurgical methods. Most of the effort has been directed toward cold pressing and sintering although some work has been done on warm pressing and hot mechanical reduction, such as extrusion.

Preparation of Powder – there are several processes for producing zirconium or zirconium hydride powder, some of which were developed in the effort to make pure ductile metal. These processes include:

1. Hydrogen embrittlement of massive zirconium.
2. Acid leaching of sponge.

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3. Fused salt electrolysis of K_2ZrF_6.

4. Reduction of zirconium with calcium or calcium hydride.

5. Reduction of zirconium tetrachloride with calcium.

6. Reduction of sodium or potassium zirconium fluoride with sodium.

Processes No. 1, 4, 5 and 6 are described in more detail by Kalish in the 1953 book "Zirconium and Zirconium Alloys". Process No. 3 was worked out by the group at Horizons, Inc. of Cleveland. Of the six listed processes, only the first three are currently considered for producing high-purity powder. Good quality powder can be obtained by the calcium or calcium hydride reduction of ZrO_2, but the high-purity calcium is expensive and the fine, lacy particles have a very low bulk density.*

Some of the characteristics of these first four powders are listed in Table II and compared to arc melted sponge and iodide zirconium. In all, the metal is better than 99% pure, but there are some significant differences in the analyses. Carbon, oxygen and nitrogen adversely affect ductility and decrease corrosion resistance as do large amounts of magnesium, calcium, chlorine and silicon. Magnesium and chlorides will cause blistering of sintered compacts; they can be distilled off in vacuum at 850° C. (1560° F.) or partially leached out by acids. (Distillation must be carried out on bulk material for the powder will sinter into a ductile mass at 850° C.)

In the hydride process the ductile crystal bar or sponge zirconium is embrittled by absorbing high-purity hydrogen. The hydride is then broken into powder and ductility is subsequently restored by reversing the process – heat and high vacuum. Hydriding temperatures cover the range between 300° C. (575° F.) for the sponge to 800° C. (1475° F.) for solid massive metal; the dehydriding is at 800° C. As can be seen from Table II oxygen and nitrogen are increased during the process. Milling in an inert atmosphere can greatly reduce the oxygen contamination – see fourth from last line in Table II.

Hydride powder can be used as such, but if it is to be converted into pure zirconium powder, it must be vacuum fired and the resultant loosely caked mass broken up. This increases oxygen another 0.1%.

On the other hand, acid leached sponge is low in oxygen and nitrogen, but is rather rich in magnesium and chloride. These volatile materials may eventually be reduced by improved leaching techniques or by low-temperature prefiring of compacts before sintering.

Table II shows that zirconium powder produced by fused salt electrolysis (next to last line) appears to be about the best. Analysis for the small percentages of gases is at best a very difficult job, and before accurate comparisons can be made, one or more laboratories should analyze the sev-

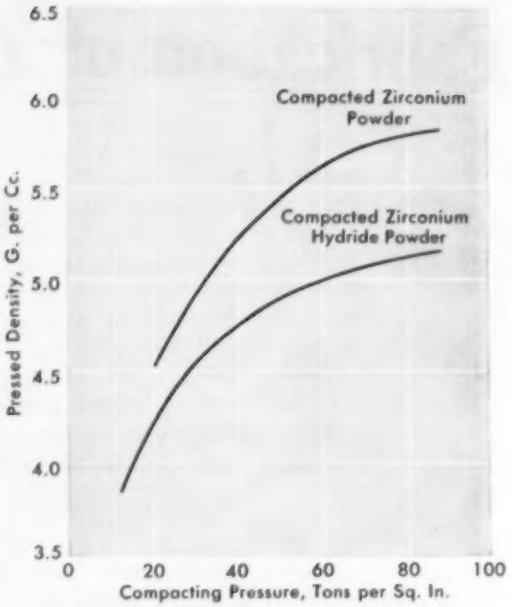


Fig. 1 – Relation Between Density of Compacts and Compacting Pressure for Zr Metal Powder and ZrH_2 Powder

*For extended discussion see "Zirconium", the latest book in the National Nuclear Energy Series, McGraw-Hill Book Co., New York.

Table I – Absorption of Thermal Neutrons for Common Elements Based on Beryllium Equals One

Element		Relative Cross Section	Melting Point
Low cross section	Oxygen	0.02	—
	Carbon	0.50	—
	Beryllium	1.00	1280° C.
	Magnesium	6.55	651
	Zirconium	20.00	1852
	Aluminum	24.44	660
Intermediate cross section	Iron	266.6	1539
	Copper	400.0	1083
	Nickel	500.0	1455
	Titanium	622.2	1725
High cross section	Hafnium	12,776	1975
	Boron	83,325	~ 2300
	Cadmium	266,640	321

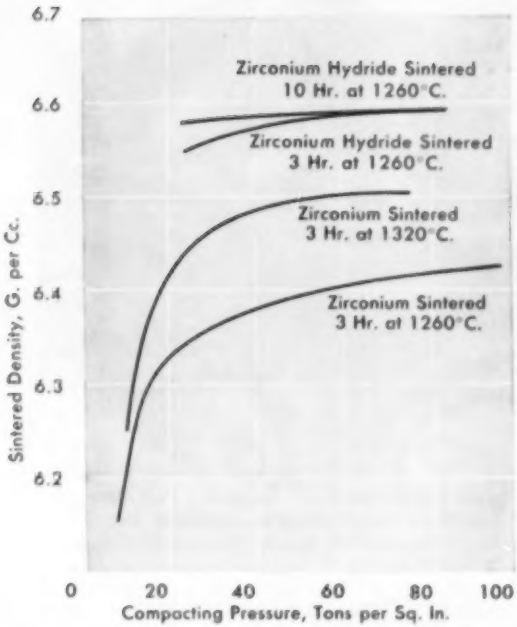


Fig. 2 – When Sintered in High Vacuum, ZrH_2 Compacts Lose Hydrogen Quickly and Sinter to Full Density

eral powders. Horizons, Inc., which made and analyzed this electrolyzed zirconium, states that arc melted ingots of their material compare very closely to arc melted Kroll sponge (listed in Table II, second line) with about twice the oxygen. Electrolytic zirconium powder can be readily handled in air whereas dehydrided zirconium powder must be handled in an inert atmosphere.

Normal zirconium contains from 2.0 to 2.5% hafnium, a high neutron cross section element, as shown in Table I. Reactor grade zirconium must not contain any hafnium and it can be separated by the chemical processes of ion interchange.* However, most of the development work has been on zirconium powder containing hafnium, but the effect of the latter is small due to its very similar chemical nature to zirconium. The theoretical density of the 2.5% hafnium alloy is 6.52 g. per cc. whereas hafnium-free zirconium is 6.49.

Cold Pressing and Sintering – By far the greatest effort has been placed on this technique using zirconium hydride and dehydrided powders. The work was carried on in this country by Hausner and co-workers and in England by Chuang (who also studied powder prepared by the leaching technique).

Hausner prepared zirconium hydride from iodide zirconium, and also made zirconium powder from the hydride. As would be expected, the hard hydride did not compact to as high a green density as the straight zirconium compound. Figure 1 shows the difference in density as determined on 2 × ⅝-in. rectangular compacts. However, sintering in a high vacuum (of the order of 5×10^{-5} mm. Hg or better) produced the reverse result. In Fig. 2, for example, the density versus compacting pressure is plotted for the two powders sintered at 1260 and 1320° C. (2300 and

*See *Metal Progress*, July 1952, p. 57.

Table II–Analysis and Properties of Zirconium and Zirconium Hydride Powders

Powder Type	Gas Content		C	Average Particle Size	Apparent Density G. per Cc.	Compression Ratio at 50 Tons/Sq. In.
	Oxygen	Nitrogen				
Arc melted iodide Zr	0.04%	0.001%	0.02%	—	—	—
Arc melted sponge Zr	0.15	0.004	0.025	—	—	—
Zr hydride from iodide Zr	0.2 to 0.4	0.005 to 0.015	—	10.3μ	2.2	2.2
Zr from decomposition of iodide hydride	0.3 to 0.5	0.005 to 0.015	—	20.0	2.0	2.75
Zr hydride from sponge Zr	0.32	0.006	—	6.8	1.96	2.27
Zr from decomposition of sponge hydride	0.4 to 0.5	0.006	—	27.4	2.33	2.2
Zr hydride from sponge Zr*	0.04 to 0.06	0.1	0.13	−200+100 mesh	—	—
Unleashed "Grade P" sponge Zr†	0.14	0.005	0.05	—	—	—
Zr from fused salt electrolysis	0.04 to 0.08	0.002 to 0.004	0.04 to 0.06	<44	—	~2
Ca-reduced ZrO_2	0.31	0.036	—	5.5	0.47	12

*As reported by Y. C. Chuang in British Atomic Energy Research Establishment Report No. X/M-87.

†A blend of several grades of distilled and undistilled sponge prepared by the Bureau of Mines, Albany, Ore. Mg is fairly low (0.05%), whereas Cl is rather high (0.13%). In "Grade A" sponge, both Mg and Cl are low (0.055 and 0.23%, respectively.) About 35% of this latter grade is produced in each reduction run.

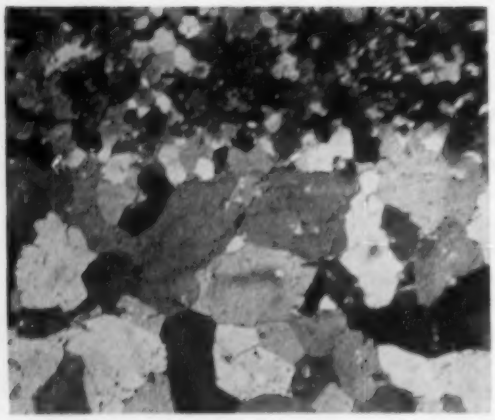


Fig. 3 – Compact Made From Zirconium Metal Powder (Top) and Zirconium Hydride Powder (Bottom). Sintered 2 Hr. at 1190° C. Note grain growth in reduced hydride. Polarized light; 100 ×

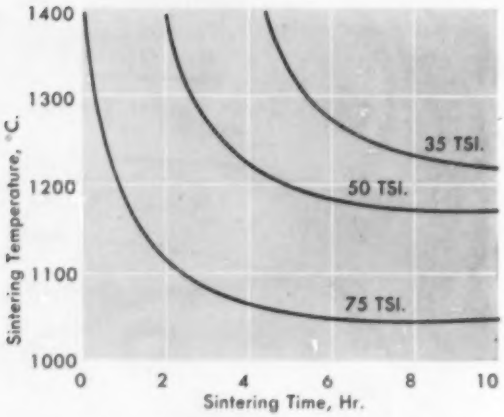


Fig. 4 – Relation Between Sintering Times and Temperatures for Achieving Full Density After Compacting at Pressures Noted. – 325-mesh ZrH_2 powder; vacuum sintering

2400° F. respectively) for 3 hr. The hydride compacts (containing 3% Hf) sintered to full density (6.59 g. per cc.) after 3 hr. at 1260° C. when compacted at 65 tons per sq.in. or higher. The metallic zirconium powder falls short of this mark even after a 3-hr. period at 1320° C. The hydride compact decomposes during the heating cycle and apparently the surfaces are extremely clean and reactive under these conditions. Theoretical density can actually be obtained by sintering a compact pressed at 50 tons per sq.in. at the relatively low temperature of 1175° C. (2150° F.) for 9 hr. If copper and iron powders behaved in a similar fashion, they would sinter to full density at 660 and 975° C. respectively (1220 and 1780° F.), but in actual fact, most pure metal powders never reach theoretical density as sintered. Zirconium is indeed unique in this respect.

In Fig. 3 the difference in microstructure is illustrated. Zirconium powder was pressed at 50 tons per sq.in. on top of a lightly pressed ZrH_2 compress and sintered for 2 hr. at 1190° C. (2175° F.). Very little grain growth occurred in the Zr layer whereas in the metal from the hydride it did – further evidence of its clean and reactive nature. Some porosity exists in the upper Zr layer, but intimate bonding occurred between the two.

Theoretical density can be achieved with zirconium hydride at pressures as low as 35 tons

Table III – Mechanical Properties of Zirconium Compacts

Material	Compacting Pressure	Sintering Temperature	Theoretical Density	Rockwell Hardness	Ultimate Strength	% Cold Rolling Before Cracking
Iodide Zr	—	—	—	B-38	40,750	60->99
Sponge Zr	—	—	—	B-84	68,500	<35
Compacted ZrH_2	50 tsi.	1260° C., 3 hr.	100%	B-92	95,000	53-72
Compacted – 100 mesh ZrH_2	48	1150° C., 6 hr.	92.5	B-96	87,400*	—
Compacted leached Zr	48	1050° C.	94.5	B-94	91,400*	—
Compacted leached Zr	48	1300° C., 3 hr.	94.5	B-95	149,200*	53
Compacted electrolytic Zr	50	1260° C., 3 hr.	95	B-88	—	—
Extruded – 80 mesh electrolytic Zr	—	750° C., 30 min.†	100	B-83	73,800	12.5‡

*Transverse rupture strength, psi. †Annealing of extrusion.

‡% elongation. Sponge zirconium treated in a similar manner will have an ultimate strength of 70,500 psi. and an elongation of 16.5%.

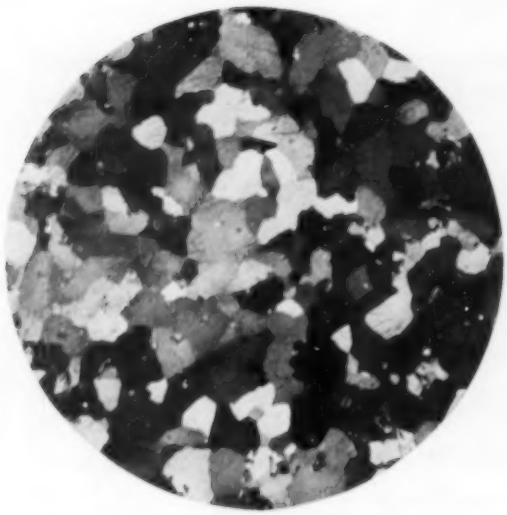


Fig. 5 – Microstructure of Electrolytic Zirconium Powder Compacted at 50 Tons per Sq. In. and Sintered in Vacuum 3 Hr. at 1260° C. HF etch-polish. Polarized light; 100 ×

per sq.in., as shown in Fig. 4. Higher sintering temperatures and times, of course, are required. With pressures of 75 tons, full density can be achieved at the very low temperature of 1050° C. (1925° F.) if held at temperature for 7 hr.

Hausner determined that graphite boats and separators proved to be best for sintering since zirconium reduced most of the common refractories it came in contact with. He further established that 1260° C. (2300° F.) is the optimum maximum temperature; above this the compacts absorb an excessive amount of oxygen. Also, compacts made from the hydride were more ductile and presumably more corrosion resistant than those made from the decomposed hydride powder, primarily because of their lower gas content. Some of the mechanical properties of the sintered hydride material are listed in Table III. It compares favorably with the arc melted products.

Chuang worked with two different types of powder, each of different quality from the above-described material used by Hausner. In one set of experiments, zirconium hydride was prepared from turnings made from graphite melted ingots of sponge zirconium. It contained 0.16% C, and relatively high nitrogen, which probably prevented high mechanical properties in the pressed and sintered compacts. Although the −200-mesh powder sintered to higher densities than the −100-mesh material, it had poorer strength, presumably due to a higher carbide content. Neither of Chuang's −100-mesh or −200-mesh powders reached the densities Hausner obtained with his very fine hydride, pressed and sintered under the same conditions.

The other powder used by Chuang was from acid leached sponge. When compacted at 48 tons per sq.in., it sintered at 1050° C. (1920° F.) to a density of 6.2; no further densification was noted up to 1300° C. (2375° F.). The mechanical properties listed in Table III show that this material is superior to the hydrided induction melted sponge and nearly equivalent to hydrided iodide zirconium prepared by Hausner.

No data are available on the relative corrosion resistance.

Small disks of zirconium powder produced by fused salt electrolysis were pressed by the present author at 50 tons per sq.in., and sintered at 1260° C. (2300° F.) for 3 hr. in a high vacuum. Resulting density was 6.25 g. per cc. and Rockwell hardness was B-88. The hardness value corroborates the low gas analysis of the original powder. Microstructure of this material is shown in Fig. 5; it appears dense, the grains are equiaxed and probably slightly larger than in compacts of dehydrided zirconium powder sintered under the same conditions.

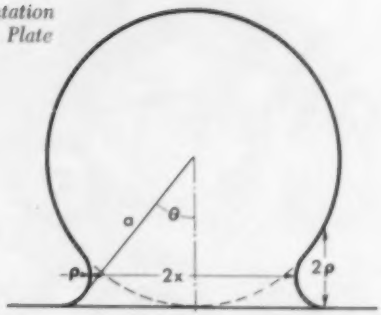
Extrusion and Pressing – Due to the rapid increase in plasticity of zirconium with temperature, full-density bodies can be produced in temperature ranges where hardened steel dies can be used. Thus, Hausner warm pressed zirconium powder obtained from the decomposed hydride at 650° C. (1200° F.) for 15 min. in vacuo at 25 tons per sq.in. The compact had a density of 6.53 g. per cc. but was slightly harder than the pressed and sintered bodies. This may have been due to contamination during the pressing operation or to the retention of volatile impurities which would be driven off during sintering at high temperature.

The author has warm pressed electrolytic zirconium powder at 550° C. (1025° F.) for 15 min. at 30 tons per sq.in. No attempt was made to exclude the air except through the close fit of the punches. Densities of 6.37 were obtained and the material had the low hardness of Rockwell B-75.

At Knolls Atomic Power Laboratory, C. J. Beck succeeded in hot extruding cold compacts of this same powder at 800° C. (1475° F.). Prior to extruding, the powder was cold pressed at 125 tons per sq.in. in a mild steel can retained in a hardened die. The can was then welded shut. No effort was made to evacuate the entrapped air. In the extrusion press reduction ratios of 11 to 1 were made and full-density rods resulted. The

(Continued on p. 160)

Fig. 1 — Schematic Representation of a Wire Bonded to a Flat Plate



The Mechanism of Sintering of Nonvolatile

THE THEORY of sintering has recently been concerned with the mechanism of mass transport, but in spite of much effort there are wide divergencies of opinion regarding transport in crystalline substances. Different schools of thought evidently exist in America and Great Britain.

In this condensed version of the paper presented at the symposium on "Powder Metallurgy in Atomic Energy" held in Philadelphia on Oct. 20 during the National Metal Congress, discussion is limited to certain experiments on the mechanism of sintering which have previously appeared only in A.E.C. reports of limited circulation. A fuller treatment of the data is presented in the original paper.

*Atomic Energy Div., Sylvania Electric Products Inc., Bayside, N.Y.

Sintering Mechanisms

At least four processes for material transport may occur during sintering and densification by heat without external pressure:

1. *Evaporation and condensation* is of little effect in metals of high melting point and low vapor pressure at sintering temperature, except possibly in the spheroidizing of angular voids.

2. *Surface diffusion* might be characterized in a similar way.

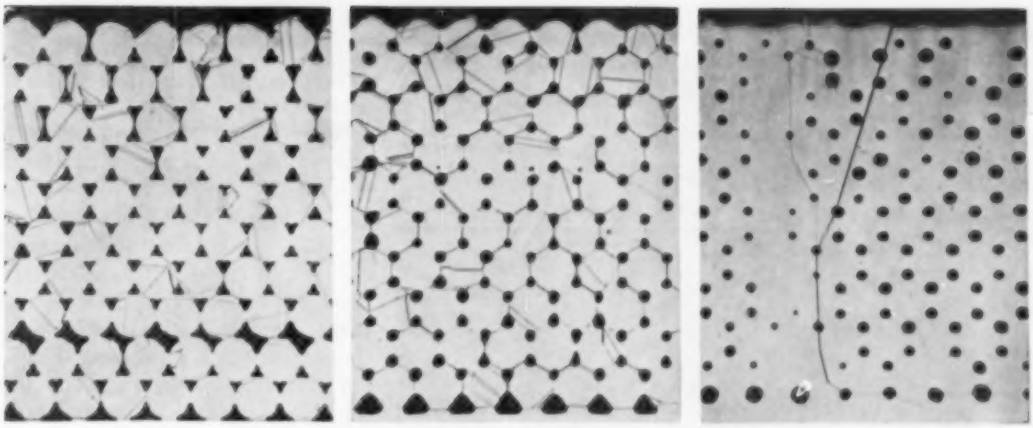


Fig. 2 – Structure of 5-Mil Copper Wires Sintered in Hydrogen at 1075° C. for 4, 32 and 408 Hr. Respectively. 35 ×

Metals and Oxides

*By LESLIE L. SEIGLE and A. L. PRANATIS**

Recently discovered evidence suggests that – in the later stages – sintering occurs by the diffusion of atoms from grain boundaries to the surface of internal voids near such boundaries. Voids isolated within grains are extremely stable. (H 15)

3. *Volume diffusion*, which originates in the random movement of atoms induced by thermal vibration. When a gradient exists, such random motion results in a net movement down the gradient. In a pure substance, such "concentration" gradients are thought to be differences in concentration of lattice defects under variously curved surfaces.

4. *Bulk flow* is the sum of all processes whereby matter is displaced in gross units under the action of stress, such as slip, viscous flow, and grain-boundary shear.

From mathematical analysis of the bonding of a wire to a flat plate as sketched in Fig. 1, it would appear that if evaporation and condensation is predominant, X^3 would vary with time; if surface diffusion is predominant, X^7 (possibly X^5 or X^3) would vary with time; if volume diffusion is predominant, X^5 would vary with time; and finally if viscous flow is the predominant process, X^2 would vary with time.

Experimental results are given at some length in our unabridged paper, and the $X^5 - t$ relationship has been found for copper spheres and wires by four different investigators and for silver wires by another. Thus it would appear that the necks between contacting wires or spheres (unless they are *very* small) grow by volume

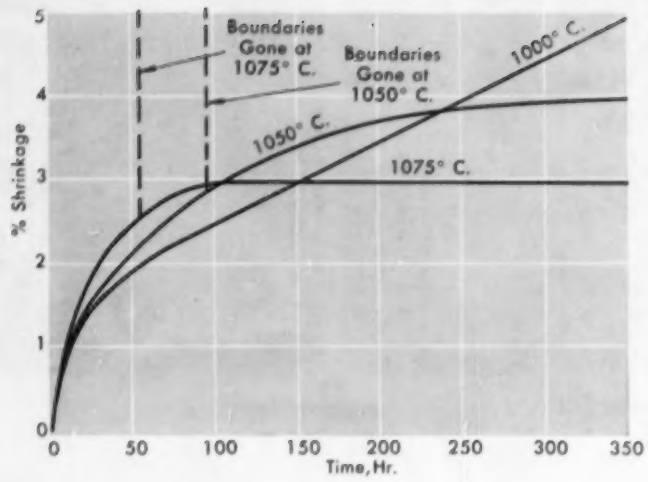


Fig. 3 — Shrinkage of 5-Mil Copper Wire Compacts Sintered in Hydrogen at 1000, 1050, and 1075° C. Original voids equal 9% of volume

diffusion. Two different studies on glass spheres, where the transport of material is by viscous flow, showed the $X^2 - t$ relationship.

Structural Effects

Let us now present some other experimental results which throw light on the basic transport mechanisms operative during the sintering of nonvolatile metals, made by Alexander and associates at the Bayside laboratory. They studied the effect of grain boundaries on the sintering rate of closely wound spools of fine copper wire. After sintering in a hydrogen atmosphere, they were sectioned, polished and the cross-sectional area of the pores was measured. An example of the changes occurring in 5-mil wires wound on ¾-in. copper spools and sintered at 1075° C. (1970° F.) for various lengths of time is given in Fig. 2 on the preceding page.

Thanks to the regular geometry of this compact, the structural changes are unusually clear. After as little as 4 hr. at temperature, grain boundaries were found connecting the three-cusped voids. As sintering proceeded, the voids spheroidized and decreased in volume. The grain boundaries remained attached to the voids until spheroidization was complete (32 hr.), and then a rapid grain growth largely eliminated grain boundaries from the compact. With their disappearance, the rate of shrinkage of the voids decreased noticeably.

An example of the data is given in Fig. 3, showing volume shrinkage vs. time at various temperatures for 5-mil copper wire compacts sintered in hydrogen. The approximate times at which grain growth occurred are noted in this figure. Although the initial rate of sintering (shrinkage) was higher at the high temperature, due to a more rapid elimination of grain boundaries, the ultimate shrinkage was less. Furthermore, it appeared from the microstructure that voids changed in size noticeably only when grain boundaries existed between them; a striking example is shown in the right-hand view of Fig. 2.

An indication of the importance of grain boundaries when sintering a normal unpressed silver powder was obtained by Balluffi. Linear shrinkage versus time plotted in a curve of much the same shape as the 1075° C. curve for volume shrinkage in Fig. 3. That is, 8% shrinkage was measured in 3.3 hr., 12% in 22 hr., and shrinkage had virtually stopped at 14% at 50 hr. The spheri-

Fig. 4 — Structure of Mass of Uncompacted Silver Spheres (− 270 + 325 Mesh) Sintered 137 Hr. at 945° C. in Argon. 150 ×

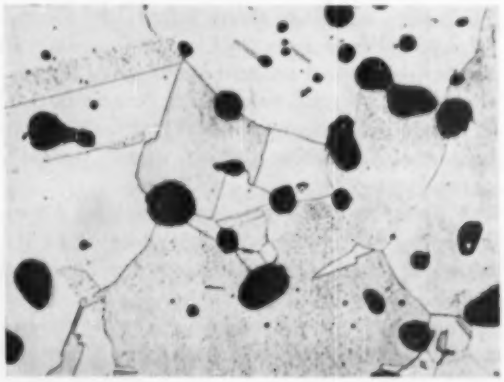
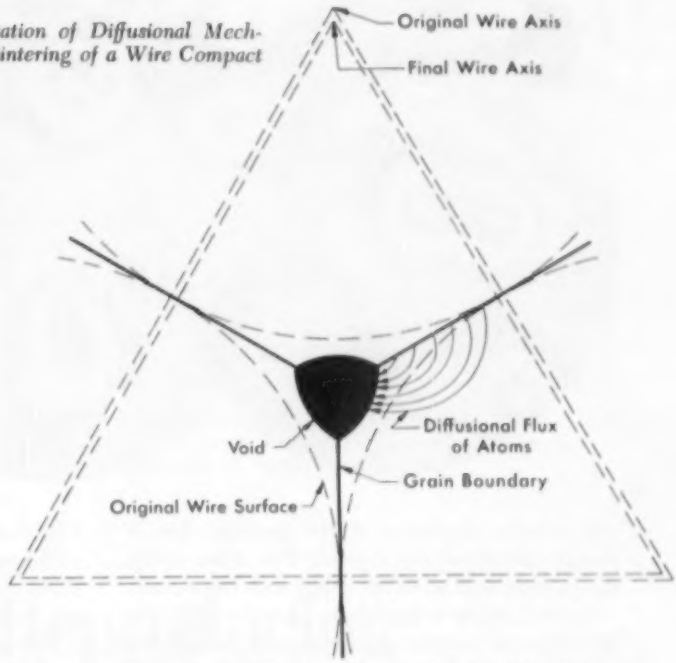


Fig. 6 – Schematic Representation of Diffusional Mechanism in Advanced Stage of Sintering of a Wire Compact



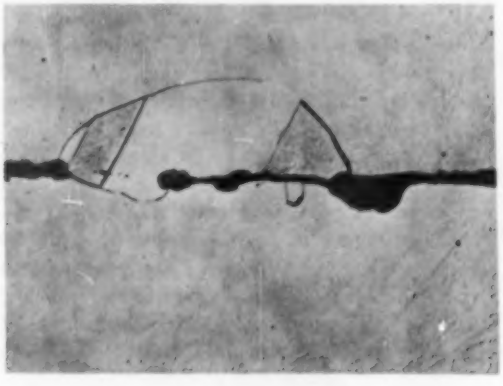
cal powder was about 2 mils average diameter (through 270 on 325 mesh); sintering was at 945° C. (1735° F.) in argon. Total shrinkage after 137 hr. at temperature was 15%.

At this time the grains had grown very large (Fig. 4) and there were many voids within the large grains out of contact with the grain boundaries. Grain growth seemed to be responsible for stopping shrinkage in the later stages of heating. The stability of voids isolated within grains in a normal powder compact has also been observed by other investigators.

In order to confirm the action of grain boundaries, Rosi in Sylvania laboratories stacked cylindrical single crystals of copper, ¼ in. diameter, in arrays with various relative orientations between neighboring crystals. After identical heat treatments some bonds were formed between crystals of like orientation, but it appeared that the number was less than between crystals of differing orientation. When bonds formed between crystals of like orientation, a grain boundary was always found at the interface, as in Fig. 5, suggesting that the orientations had not indeed been identical, or that a new grain had formed at the interface.

The influence of grain boundaries on sintering (shrinkage) rates is directly explainable by the volume diffusion mechanism suggested by Nabarro and Herring. According to this theory, voids are filled by atoms diffusing from the nearest grain boundary to the surface of the void. (Stated in terms of the lattice vacancy theory of diffusion, vacancies migrate from the void to the grain boundary.) The grain boundary acts as a source of atoms (or sink for vacancies) and as atoms leave the grain boundary, the vacant space is filled by the grains moving together. The process is represented in Fig. 6, a drawing of a wire compact in an advanced stage of sintering. For simplicity, the void is assumed to have reached an equilibrium shape. The dashed arcs give the original positions of the wires, and the lines of flux represent the current of atoms flowing from each grain boundary into the void. Meanwhile the wires have moved together so that the wire centers now lie at the apices of the inner equilateral triangle. The sum of such movements constitutes the over-all shrinkage of the compact. When grain boundaries are no longer present to act as nearby sources of atoms, the void practically stops shrinking.

Fig. 5 – When Copper Single Crystals Are Placed With Identical Orientations and Heated, a New Grain Forms at Point of Contact



This concept has received strong experimental support from the work of at least four different sets of researchers.

Marker Movements

A direct indication of the transport process can be obtained by studying the position of inert markers. It is known that an inert solid particle

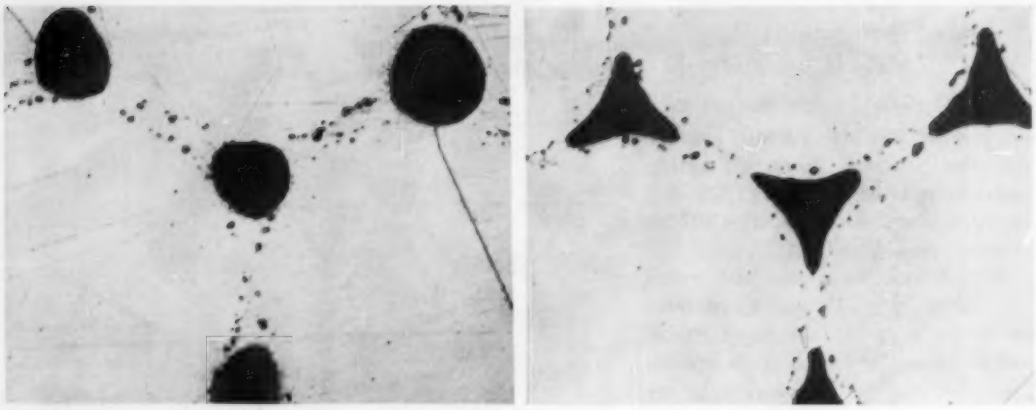


Fig. 7 – Compacts of Copper Wire (With Colloidal Graphite Particles Near Original Surface) Sintered in Hydrogen at 1070° C. for 7.5 (Left) and 95 Hr. (Right). 50 ×

will remain stationary if the material flux is purely diffusional, but if plastic flow is occurring, the particle will be swept along with the stream.

Several attempts have been made to apply this technique to copper wire compacts, using fine particles of graphite, tungsten, or Al_2O_3 as inert markers on or just beneath the wire surfaces. The appearance of a typical compact is shown in Fig. 7. If the sintering mechanism indicated in Fig. 6 were valid, one would expect the markers to remain in a circular configuration of constant diameter, and the circles to approach each other. Experiments performed to date indicate that the particles do not move out of their circles during sintering. However, the circles do not approach each other because the entire wire compacts with embedded "inert" markers do not shrink. For some reason not yet understood, the markers influence the behavior of the compact. Extensive bonding occurs between wires, and voids tend to spheroidize in the usual manner, as shown in the left-hand micro of Fig. 7, but the void volume remained almost constant. In Fig. 7 at right, the material to fill the cusps has evidently migrated from the nearby surface of the void, as shown by the proximity of the markers to the surface which has been depleted.

Summary and Conclusions

Before attempting a final evaluation of the evidence we should emphasize the possibility that different sintering mechanisms may occur in a single material depending on the circumstances. For example, as particle size is decreased and the ratio of surface area to volume increased, surface diffusion probably becomes important. Plastic deformation might also be favored in the very early stages of bond growth between particles when the curvature of the "neck" or meniscus is sharp, and stresses there quite high.

It is probably an oversimplification, therefore, to describe sintering in terms of an isolated mechanism. Nevertheless, the evidence convinces us that *volume diffusion* is the rate-controlling process in all but the initial stages of sintering of normally sized particles of nonvolatile metals and oxides. This conclusion is borne out by the neck growth studies of Kuczynski and others, observations of the influence of grain boundaries by Alexander, studies of the growth and shrinkage of pores by Rhines, and investigations of the effect of impurities upon the sintering rates of oxides by Weyl and others. Although the weight of evidence is felt to rest upon the side of a diffusional mechanism for nonvolatile metals and oxides, it must be admitted that the basic data are far from extensive.

Finally, we desire to re-emphasize the influence of grain boundaries upon sintering rates, and the interpretation of this effect by the Nabarro-Herring mechanism. We believe this interpretation has not yet received deserved attention among powder metallurgists, although it has been successfully applied to creep at high temperatures under light loads, mass flow during diffusion, and other high-temperature phenomena. Since the theory of mass transport at elevated temperatures by diffusion of individual ions between grain boundaries and free surfaces has been confirmed by a variety of experiments, it cannot be ignored as a possible explanation of many sintering phenomena.

Reproducing a Roman Coin

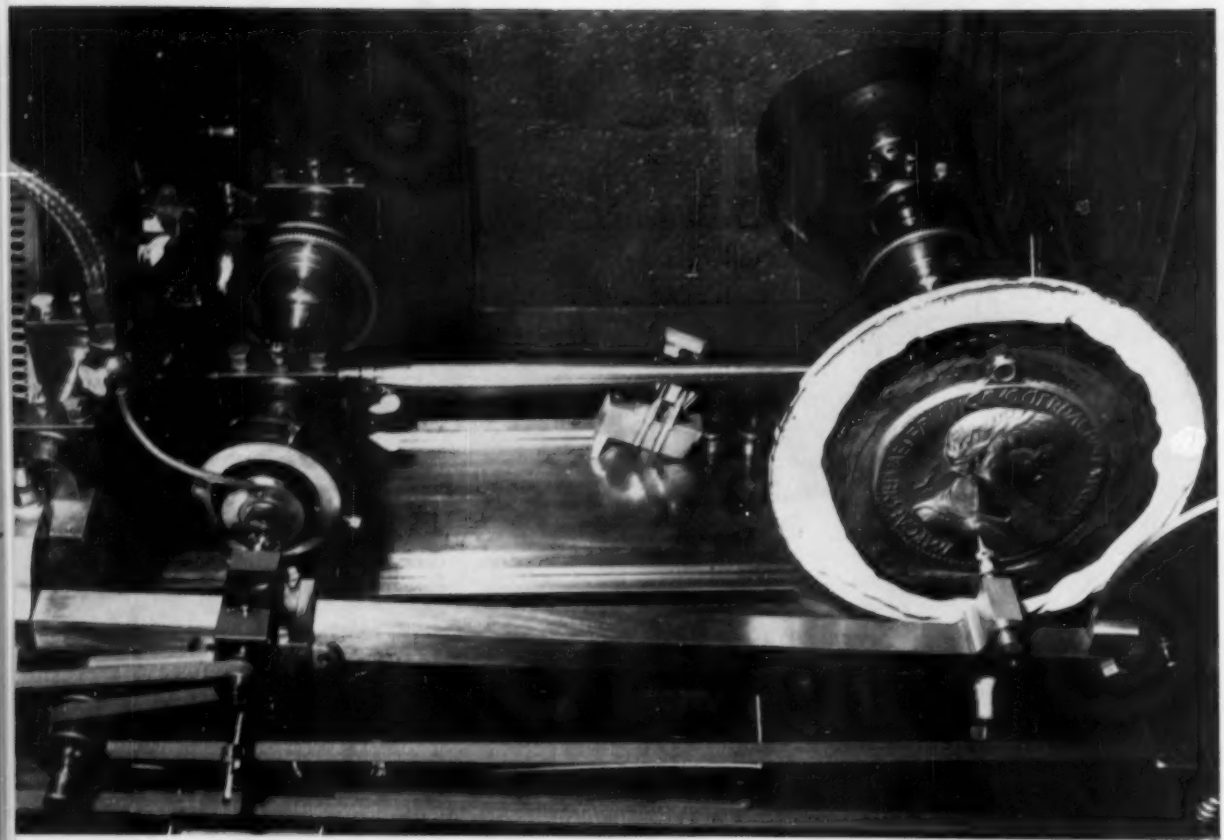
*By E. W. HORVICK**

Production of replicas of a Roman coin for ornamental use is described pictorially (G 3, Zn)

PRODUCTION of small pieces of jewelry in large quantities requires an unusual combination of art and engineering to obtain an attractive ornament at a competitive price. When U.S. Time Corp. wanted replicas of an authentic Roman coin to be worn on a watch chain, they engaged Medallic Art Co. to produce them in quantity. The coin selected was one issued in the reign of Emperor Caesar Nerva; the production technique was to stamp from zinc strip and hard finish.

To reproduce exactly every minute detail of the original, a talented sculptor prepared a model 8 in. in diameter from which the dies were subsequently prepared.

*American Zinc Institute, Inc., New York, N. Y.

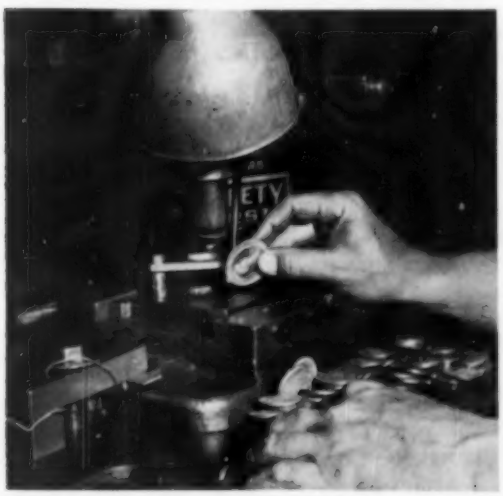


The tracer of the reducing machine meticulously explores the surface and detects every feature. The motion pattern of the tracer is scaled down and transmitted to a cutter which automatically cuts into soft die steel an exact reproduction of the sculptor's model.

The die is heat treated so that the surface is hard enough not to deform and yet the core is sufficiently soft to absorb the impact of the operation without damage to the die. Good control of heat treatment is essential to maintain the fine surface details throughout the production run.

◀ Blanks are punched from 0.128 by 6-in. zinc strip on a punch press. The blanks are circular disks with a projection for the ring attachment element. U.S. Time Corp. chose zinc for making the ancient Roman replicas because it is easily formed and finished, it won't cause stains from corrosion and its price is low.

The blanks are inserted one at a time by hand into a 400-ton knuckle joint press. The definition sought in fine medallic work usually requires from three to five strikes to bring out the delicate craftsmanship. ▶



◀ The precision struck medal has a flash of waste metal around the edges which must be removed. Each coin is placed in a die on a trimming press and the flash is neatly trimmed off leaving a comparatively smooth, round edge.

Remaining unevenness around the periphery of each piece is buffed. Each medal is sand-blasted to give the zinc a velvety richness of texture, then oxidized, polished and relieved by hand to bring out the antique effect. A lacquer coat is applied to preserve the patina. ▶

Thus a fine arts replica is created, an exact miniature of an authentic museum piece.

Fig. 1 – Stainless Steel Screw Used to Evaluate Cleaning Efficiency

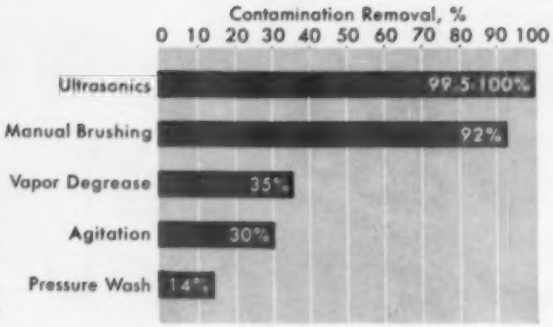


Fig. 2 – Amount of Radioactive Contamination Removed by Various Cleaning Methods

Evaluating Metal Cleaning Efficiency

*By T. J. BULAT**

Radioactive soils are used to measure accurately the efficiency of various cleaning methods. Ultrasonic cleaning proved to be the most effective. (L 10)

MANY manufacturers are now using ultrasonic equipment as an accepted parts-cleaning tool in production processes. Because such equipment is comparatively expensive, a major problem is to determine exactly how much the efficiency of cleaning can be improved by its use.

Visual, microscopic, or chemical tests are limited because they are unable to detect contaminants either present in extremely small amounts or located in blind holes, crevices and hidden channels. Because radioactive contamination, even though minute, can be readily detected in these hard-to-reach places, radioactive soils are ideally suited for accurate measurement of cleaning efficiency. We used radioactive oil (medium heavy lubricating oil), radioactive buffing compound (chromium oxide) and radioactive metal chips. The general procedure was to contaminate a part with one or more of the radioactive soils. The amount of radiation emitted before and after cleaning was recorded. From these data, the exact percentage of contamination removed by any particular cleaning operation could be accurately computed.

A group of stainless steel screws similar to that shown in Fig. 1 were coated with a thin film of radioactive oil and radioactive buffing compound. To intensify the cleaning problem, the screws were baked 4 hr. at 400° F., thus making the contaminant very resistant to cleaning, and simulating, to some extent, "setting-up" conditions which take place when parts stand idle for a period of time on a production line or in storage. These screws were then cleaned by the following methods:

1. Vapor degrease using a chlorinated solvent.
2. Pressure wash, using a pressurized stream of Stoddard solvents.
3. Agitate mechanically for 10 min. in a petroleum solvent.
4. Scrub manually with a fine wire brush in Stoddard solvent.
5. Clean by magnetostrictive ultrasonics for 2 min. in a water-detergent solution. The equipment used was a Bendix UC-12 ultrasonic cleaner unit with 6-gal. capacity.

The results of this experiment are shown in Fig. 2. Only 14% of this contamination was re-

*Pioneer-Central Div., Bendix Aviation Corp., Ultrasonic Applications Lab., Davenport, Iowa.

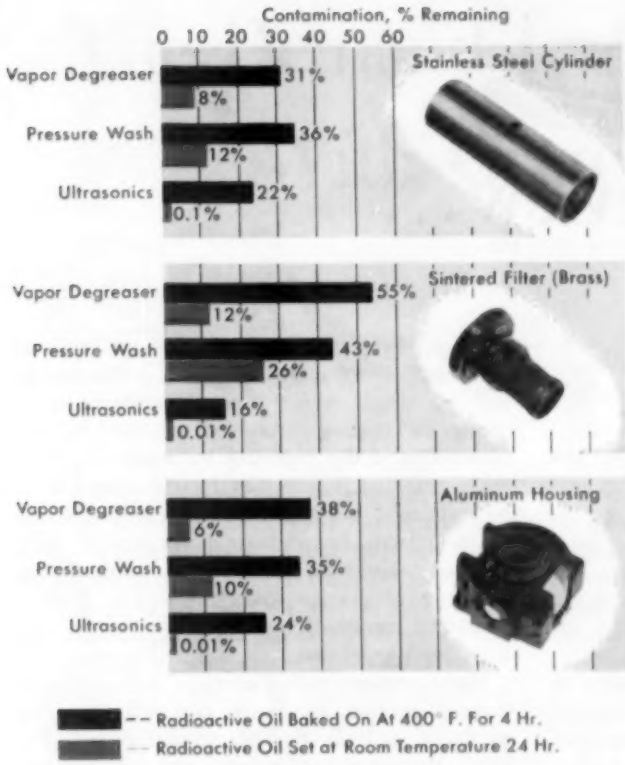


Fig. 3 – Evaluation of Cleaning Methods for Small Complex Components

moved by the pressure wash, 30% was removed by agitation, 35% by vapor degreasing, 92% by manual brushing and 99.5% by magnetostrictive ultrasonics. Solvent action alone was not enough to remove the contamination from the parts; an actual physical action was also needed. Hand brushing provided this but was unable to penetrate the tapped hole effectively. Ultrasonic action was potent enough to remove surface contamination and in addition penetrated the tapped holes with a remarkable cleaning action.

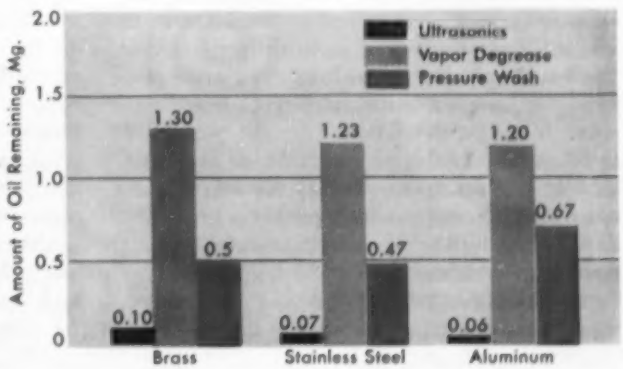
To check the effect of alloy composition and configuration, the stainless steel cylinder, brass sintered filter and anodized aluminum housing shown in Fig. 3 were tested. The parts were divided into two groups. Both groups were coated with radioactive oil. One group was allowed to set for 24 hr. prior to cleaning, the other was baked 4 hr. at 400° F. to make the cleaning more difficult. Three cleaning systems were used: vapor degrease in chlorinated solvent, pressure wash using Stoddard solvent, and ultrasonics using a water-detergent solution. The results of this experiment on the three different parts are shown in Fig. 3.

The superiority of low-frequency magnetostrictive ultrasonics in the cleaning of a complicated part is obvious, especially in the cleaning of the sintered brass filter. Ultrasonics was far more effective than other methods in penetrating the interstices of this part.

To check the effect on parts of simple configuration, plain metal blanks of brass, stainless steel, and aluminum were used. The blanks were coated with radioactive oil and allowed to set for 24 hr. at room temperature. They were then subjected to the same three cleaning systems as described above for the complex parts. The original amount of radioactive oil deposited on each blank was approximately 50 mg. The results, as shown by Fig. 4, were calculated in milligrams of oil remaining after cleaning.

Ultrasonics cannot cope with all metal cleaning problems and is not always practical. Definite advantages are gained, however, by low-frequency magnetostrictive ultrasonic cleaning on a great variety of production problems. It is a potent tool in modern metal cleaning processes and shows even more promise of further achievement in the very near future.

Fig. 4 – Evaluation of Cleaning Methods for Parts of Simple Configuration



Book Review . . .

A Six-Billion Dollar Problem

Reviewed by
*FREDERICK A. LOWENHEIM**

PROTECTIVE COATINGS FOR METALS, by R. M. Burns and W. W. Bradley, 2nd Ed., 1955. A.C.S. Monograph No. 129, Reinhold Publishing Corp., New York City. 643 p., $12.

ONE OF THE exasperating properties of man's most useful metals, iron and steel, is their tendency – if an anthropomorphic metaphor may be permitted – to go native. Having existed for geologic ages in the form of iron oxides, they tend to revert to this natural condition on the slightest provocation. Most of the other metals used as structural materials in modern civilization exhibit similar tendencies, although perhaps to a somewhat lesser extent. Dr. Uhlig, who wrote the foreword to the book, has elsewhere estimated that the annual world cost of replacing and repairing corroded materials and equipment is of the order of six billion dollars. There can be no doubt that corrosion represents a major problem to designers, engineers and metallurgists and all others concerned with the planning, construction and maintenance of the countless metallic components – from screws to bridges, from the tiniest electrical contactor to the longest pipeline – which together make possible our complex industrial way of life.

Much of this deterioration by the process of corrosion is probably unavoidable, or avoidable only at exorbitant expense. On the other hand, much of the corrosion which quickly or gradually destroys the utility or appearance of so many materials and fabrications could be prevented – by greater foresight in design, by intelligence and knowledge in specification of materials of construction, by more care and craftsmanship and by simple honesty in the application of protective coatings. Any contribution to our knowledge of the processes by which corrosion takes place or how it can be minimized is to be welcomed, whether it be a theoretical study of the electrochemical fundamentals, a more practical discovery of improved methods, or a survey of present knowledge. The present book is a contribution of the survey type, and it is a very good one.

Many readers will remember with pleasure the first edition, by Burns and Schuh, which appeared in 1939. For the second edition Dr. Burns, the senior author, has a new collaborator, and together the authors have thoroughly revised, enlarged, brought up to date and improved an already outstanding book. As the title implies, it is strictly limited in its coverage and is not – nor does it make any claim to be – a complete handbook on all phases of the complicated corrosion problem.

Taking the basis metal as given, the book is concerned with the properties, method of application and the fields of usefulness of protective coatings, both metallic and organic. As anyone familiar with Dr. Burns's editorial writings in the *Journal* of the Electrochemical Society would expect, the book is well and clearly written; it avoids literary pretension on the one hand, and on the other the semiliterate technical jargon which disfigures so much present-day "scientific" writing. Mechanically the book is up to the high standards of its publisher and the A.C.S. monograph series; it is well proof-read, bound and illustrated. The price is not high by contemporary standards.

Although not so divided in the table of contents, the book falls naturally into five main parts: *(a)* principles of corrosion (Chapter 1), *(b)* preparation for coating (Chapter 2), *(c)*

(Continued on page 148)

*Supervisor, Electrochemical Research, Metal & Thermit Corp., Rahway, N.J.

The Demand for Metallurgists With Graduate Training

*By J. H. HOLLOMON and J. J. BECKER**

Industry and universities need between two and four times as many metallurgists with advanced degrees as are available. No relief of the shortage is in sight. (A 3)

IN THE AUGUST 1955 issue of *Metal Progress*, Bever described the results of a survey of the supply of metallurgists with advanced training from schools in the United States. The significance of his data can best be appreciated when the supply is compared with the demand. It is difficult to estimate the future demand because it is more subject to short-term influences than the supply and can change more rapidly. Furthermore, the number of employers and potential employers of metallurgists with advanced training is large, so that any study must be statistical rather than exhaustive.

To determine where graduate metallurgists are employed, a questionnaire was sent to a selected sample of the 48 schools which grant graduate degrees in metallurgy. Usable replies were received from 17 institutions. Each listed the number of students who had received advanced degrees during the period 1948 through 1954 and named either their present employers or their employers immediately upon graduation (usually the latter). We thus obtained information on 452 individuals who received advanced degrees in metallurgy during the six-year period. These 452 people were employed by 183 different organizations in the United States as classified in Table I. Academic institutions include both faculty appointments and those working on research projects. "Research Foundations" refer to such institutions as Battelle and Armour. "Miscellaneous" includes unspecified private business or departures from the metallurgical field.

Bever's survey of this same six-year period showed that 337 Ph.D. degrees were granted

*General Electric Research Laboratory, Schenectady, N. Y. This study is part of a more general program being carried on by a "Committee for the Metallurgy Profession", an unofficial group Chairmanned by Prof. M. Cohen of Massachusetts Institute of Technology.

Table I – Employers of Graduate Metallurgists Direct From Universities, 1948 to 1954

TYPE OF EMPLOYER	NUMBER OF EMPLOYERS	M.S.	PH.D.	NOT SPECIFIED	TOTAL	% OF M.S.	% OF PH.D.	% OF TOTAL
Academic	31	19	46	—	65	8	24	14
Aircraft	10	11	3	—	14	5	1	3
Automotive	3	5	9	—	14	2	5	3
Chemical	8	18	25	1	44	7	13	10
Electrical	15	44	40	—	84	18	20	19
Government	22	26	17	—	43	10	9	10
Machinery and equipment	25	26	6	—	32	10	3	7
Materials producers and fabricators	47	68	29	3	100	27	15	22
Oil	7	5	6	1	12	2	3	3
Research foundations	5	20	11	2	33	8	6	7
Miscellaneous	10	8	3	—	11	3	1	2
TOTALS	183	250	195	7	452	100	100	100

by 32 institutions. This number includes substantially all of the Ph.D.'s produced. Bever believes that about 10% were foreigners who left the country after obtaining their degrees. Thus, the number available for employment in the United States during this period would be approximately 300 and our survey included information on 195, or about 65%. To determine the percentage of those obtaining the M.S. degree is more difficult. Many (Bever estimates 25%) continue their training to obtain doctorates in metallurgy and a small unknown number go on to doctorates in other fields. Furthermore, Bever estimates that about 10% are unavailable to United States employers. The figure is further complicated by the fact that many who study for M.S. degrees are already employed. Nevertheless, we can estimate that slightly over 500 M.S. students from Bever's total of 1033 were available for employment. Thus, the data in Table I represent a sample of approximately two-thirds of the Ph.D.'s and 40 to 50% of those who obtained M.S. degrees and were available for employment.

It is interesting to note that the academic institutions themselves hired the largest number of the Ph.D.'s – about one-quarter of them. When the M.S. and Ph.D. figures are taken together, the materials producers and fabricators employ the largest number. Of the total the metal producers and fabricators hired about 25% while the metal-consuming industry hired about 50% – twice as many.

In interpreting these figures, it must be remembered that the real share taken by any one group is determined by that group's growth in size. If, for example, the Ph.D.'s taken by universities merely represent turnover in a group whose size is static, their numerical effect on the market is much less than otherwise.

Projected Needs for Graduate Metallurgists – A questionnaire was then sent to a selected group of employers representative of the types shown in Table I. Twenty-seven usable replies were received. These 27 employers, during the six-year period studied by Bever, hired a total of 377 metallurgical M.S.'s and Ph.D.'s, which included 175 of the 452 students represented in the preliminary survey. That is, slightly less than half of their total hiring represented people who had just obtained their degrees. Of these 377 people, 188 were Ph.D.'s and 189 were M.S.'s, but only 74 of these Ph.D.'s and 101 of the M.S.'s came directly upon graduation. Distribution among the types of employers is shown in Table II.

Table II – Graduate Metallurgists Employed by 27 Representative Firms

Type of Employer	Number of Employers	M.S.	Ph.D.
Academic	3	11	51
Aircraft	2	6	4
Automotive	1	6	3
Chemical	2	16	18
Electrical	2	45	31
Government	4	24	18
Materials producers and fabricators	10	41	39
Oil	1	6	4
Research foundations	2	34	20
Total Employed, 1948 to 1954	27	189	188
Estimated Requirements 1955 to 1960	27	334	365

In the questionnaire, the employer was asked to predict the number of metallurgists with advanced degrees that he would need for the next six years beginning with 1955. The demand for M.S.'s was about 55 on the average for the next six years, compared with 30 hired during the previous six. Similarly, the number of Ph.D.'s wanted is about 60 compared with an average past hiring of about 30 per year. Since the "future" figures tend to reflect what a given employer thinks he may be able to get – as well as what he would like ideally – they will tend to be conservative. For these 27 employers, then, the demand appears to be at least twice that of past hiring. This estimate represents a minimum demand as far as the schools are concerned, since only half the people these employers previously hired came directly upon graduation. If they had to rely entirely on the schools for their future supply, the demand on the schools would be four times the present supply. This estimate of demand is reinforced by the answers to the question, "Had the supply been unlimited, how many would you have hired?" Those who replied to this question hired 228 and said they would have liked 405.

Our sample of 27 employers did roughly a quarter of the total hiring during the period studied. Thus their statement that they want at least twice what the supply has been may be taken as typical of all employers. This means that the demand in the coming year will be for at least 120 to 150 Ph.D.'s and an equal number of M.S.'s for direct placement upon graduation.

Table III – Metallurgical Personnel in U.S. Academic Institutions

Academic Staffs	Reported by 44 Institutions	Estimated U. S. Totals
Tenure staff		
Teaching	70	—
Teaching and research	106	—
Research	9	—
Total	185	210
Nontenure staff, total	106	125
Staff positions open (immediate need)		
B.S.	3	—
M.S.	6	—
Ph.D.	40	—
Total	49	55
Staff positions filled and available, total	340	390
Annual needs for continuing replacement of staff		
B.S.	8	—
M.S.	7	—
Ph.D.	48	—
Total	63	13*
Graduate students enrolled	410	490
Reported annual needs of B.S. for graduate training	231	260

*Estimate based on steady state replenishment *only* on the assumption of a professional lifetime of 30 years. Needs in the immediate future are *much* higher due to anticipated increase in staff level.

About one third of those who replied commented on the training of the people they hired. Almost without exception, they wanted people better trained in the basic disciplines of chemistry and physics and more capable of attacking varied and unusual problems. The specialization of present training was decried by several.

Academic Needs – To estimate the need of academic institutions for metallurgists with graduate training, Cyril S. Smith and Reinhardt Schuhmann carried out a separate study, from which we quote:

"A questionnaire was sent to 68 institutions believed to be engaged in metallurgical training in this country; 44 were returned.

"The results given in Table III should be used with care since some ambiguities and omissions became apparent in the questionnaire, including poor distinction between men and institutions of widely differing types and inadequate separation between immediate needs and needs for continual replacements.

"The total number of staff appointments in metallurgy is 390, including 55 positions without incumbents at the moment. This represents an urgent immediate need but not a recurring one unless metallurgical education should expand unexpectedly. If replacements of the staff of 390 are to be made only as a result of retirement only about 13 replacements would be needed per year. The fact that the replacement need totals 63 per year (for the reporting institutions only) means, of course, that many individuals transfer from one institution to another in mid-career. If these transfers occur between one academic institution and another, they clearly do not represent a net academic need; if to industry, the academic need remains but the industrial need is relieved. Continuing needs for metallurgists can perhaps best be arrived at from an estimated professional life expectancy at graduation and the total level of employment rather than by summing the supposed individual needs as reported by the institutions.

"The replies indicated that many colleges are anxious to extend their facilities for metallurgical training. They definitely want specialized metallurgists, with only an occasional desire for people trained in the more basic disciplines of physics and chemistry. It was interesting to note that although Ph.D. training is generally regarded as necessary, many staff positions, including some with tenure, are available without advanced training."

Summary – The academic institutions themselves appear to require immediately 55 Ph.D.'s out of an estimated annual supply of 60 to 80. The total demand for industry and academy appears to be 120 to 150 Ph.D.'s and 120 to 150 M.S.'s per year, while Bever forecasts a supply of 60 to 80 Ph.D.'s and 100 to 135 M.S.'s. The last figure must be reduced by the "sizable fraction" already employed. Metal consumers hire twice as many graduate metallurgists as metal producers and fabricators. About half of the hiring done during the period studied was of people fresh from school. There is a strange divergence between the type of people required, at least on the basis of these two different inquiries; the schools apparently want people with specialized training and experience, while industry wants people more basically trained in physics and chemistry.

The shortage of advanced-degree metallurgists is most significant and urgent. Academy, industry and Government must cooperate to meet it quickly and successfully.

Nickel Conservation With High-Manganese Stainless Steels

*By FRANKLIN P. HUDDLE**

Between a half and two thirds of the nickel-bearing stainless steels could possibly be replaced by the high-manganese alloys, A.I.S.I. Type 201 and 202. The base price difference favors selection of the manganese steels. (SS)

UNREMITTING efforts by the Federal Government to improve the mobilization position of the United States in respect to nickel have not yet succeeded in establishing adequate supplies and reserves of this metal.

The stockpiling act has been in effect for nine years and the defense production act for five years; these authorizations have helped our mobilization position in many ways. Some progress has been made in nickel stockpiling; contracts have been placed with a number of foreign producers of nickel; production of nickel oxide under United States Government sponsorship has been undertaken in Cuba; and a major source of ferronickel has been developed in the United States. But we are still not on easy street. In fact, in terms of all national requirements nickel is short today and the shortage seems likely to continue.

During the Korean emergency American industry used boron rather extensively in constructional alloy steels. Considerable use was made of stainless steel cladding. The pattern of nickel conservation in stainless steels was shaped by the National Production Authority in Order M-80 prohibiting the use of stainless steels containing more than 1% nickel for a long list of industrial applications. In response to this order many users shifted from austenitic to straight chromium stainless steels of the A.I.S.I. 400 series. In addition, several austenitic compositions were worked out using high manganese and chromium content along with the permitted 1% nickel. The 400 series proved unsatisfactory for applications requiring nonmagnetic properties and untreated welds. The low-nickel compositions were successful in a few limited uses. With the termination of the Korean emergency, the pressure for nickel conservation in this direction diminished.

In a free economy price is king and economics undoubtedly played a decisive role in the revived heavy use of nickel. Meanwhile, many new uses for nickel are being foreshadowed – especially in stainless steel. High-temperature skins for aircraft, high-temperature jet engines and engineering steels are pre-empting nickel in increasing quantities. In nickel-bearing stainless steels alone, the mills poured 430,798 ingot-tons in

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1953, 468,689 in 1954, and for the first six months of 1955 were producing at the annual rate of 649,560 tons.

In consequence, industry today is experiencing the unprecedented phenomenon of a peacetime shortage of nickel – without knowing where and when it will end.

Since 1950 the military departments have been making good progress in learning how to get along with less nickel in many items in which nickel has historically been indispensable. Efforts in this direction are continuing. Eventually the Armed Services may eliminate nickel altogether, or virtually so, from such military staples as armor plate, gun mounts, tank components and salt water piping. The amount of nickel required for mobilization has been steadily reduced, and this trend will continue.

But while the military departments pursue conservation in equipment design, requirements of nickel, both military and nonmilitary, for current production have been creeping upward. Unless the present trend in nickel usage can be arrested or at least slowed down, it will be responsible for many peacetime procurement headaches and might create a serious wartime hazard despite military conservation efforts.

A great many items purchased by the Military Services in wartime are standard equipment over which the Services exercise no design control. These include multi-purpose components (such as fractional horsepower motors) and commercial or shelf-type items (such as bulldozers and typewriters). To some extent, even here, the Military Services are attempting to awaken manufacturers to the necessity for mobilization planning. Manufacturers are today being asked to consider whether they would be able to produce under mobilization circumstances substantially the same item they are now making, using leaner alloys and eliminating the critical material content wherever possible.

It might be of interest to compare this very modest approach with what we are told about another country. According to an article in *Automotive Industries* of about a year ago, civilian industry and organizations in the U.S.S.R. are intensively adapted to military requirements:

"Regardless of costs and lowered economic efficiency, the specifications of many civilian products have been changed to conform to military needs. A notable illustration is the change-over from wheeled to track-laying tractors for Soviet agriculture in the mid 1930's. A current example is the production 'for agriculture' of the GAS-69, 4 × 4 weapons carriers."

The extreme practice cited for the Soviet Union would probably not be warranted or even possible in the United States. However, the fabricators and users of metals in this country, in the interest of the national security, should give more attention to the important matter of optimum utilization of materials in peace or war.

The present pressure of nickel shortage upon both producers and fabricators of nickel-bearing stainless steels provides motivation for general exploration of ways to make nickel go further – to give more service per pound employed. One very attractive opportunity lies in the use of low-nickel manganese stainless steels.

According to the American Iron and Steel Institute, during the first six months of this year the mills poured 325,000 ingot-tons of nickel-bearing stainless steels of which 41,000 were Type 301, 106,000 were Type 302, and 78,000 were Type 304. During this period more than two-thirds of all stainless steels produced were possible candidates for replacement by the manganese-type stainless steels. Composition limits established by A.I.S.I. for these steels are shown in Table I.

Table I – Composition Limits of High-Mn and Conventional Stainless

Type	C*	Mn	Cr	Ni	P*
201	0.15	5.5 to 7.5	16.0 to 18.0	3.5 to 5.5	0.06
202	0.15	7.5 to 10.0	17.0 to 19.0	4.0 to 6.0	0.06
301	0.15	2.00*	16.0 to 18.0	6.0 to 8.0	0.045
302	0.15	2.00*	17.0 to 19.0	8.0 to 10.0	0.045
304	0.08	2.00*	18.0 to 20.0	8.0 to 12.0	0.045

*Maximum. In all types sulphur is 0.030 max., and silicon 1.00 max. Types 201 and 202 contain 0.25 max. nitrogen.

For much of the factual and technical material concerning properties and production of manganese-type stainless steels in the rest of this paper, I am indebted to a staff study* by Edmund V. Bennett for the Materials Advisory Board, National Academy of Sciences – National Research Council, prepared at the request of the Department of Defense.

According to Mr. Bennett, the present usage pattern (see Table II) is that about 8% of all

*A limited number of copies of Mr. Bennett's report are available for distribution to industry. Requests may be addressed to Robert Burns, executive secretary, Materials Advisory Board, National Academy of Sciences – National Research Council, 2101 Constitution Ave., Washington 25, D. C.

austenitic stainless steel is Type 301, 23% is Type 302 and 27% is Type 304. Major consumers of 301 are railroads and automotive equipment, using more than half the 301 produced. Major consumers of 302 are aircraft and domestic appliances, which take nearly half of this type. Nearly half of the 304 is used in automotive, aircraft, food-processing and special-purpose industrial equipment. The 201 and 202 manganese-type stainless steels would certainly be suitable for some of these applications.

Virtually all nickel consumed in the United States is imported. Fortunately, from the defense standpoint, the major source is our close neighbor, Canada; the second source in importance is Cuba, also close at hand. Imports in recent years are as follows:

Year	Net Tons*
1950	91,347
1951	93,190
1952	108,850
1953	118,737
1954	131,789
1955 (6 mo.)	73,442

*Source: U. S. Bureau of Mines

In comparison with the 73,000 tons of nickel imported in the first half of this year, about 16,000 tons, the largest single use, was consumed in stainless steels (shipped weight). Of this total, 1561 tons went into 301, 5136 tons into 302 and 4218 into 304.

In summary, stainless steels consume about one-fifth of all nickel currently available. One-half to two-thirds of the nickel-bearing stainless steels are candidates for substitution of low-nickel manganese stainless steels. The manganese-type stainless steels require only about one-half the nickel used by conventional austenitic steels. The possible nickel saving by this substitution is thus on the order of 5 to 10% of all nickel now being used.

The conclusions of Mr. Bennett's evaluation of low-nickel manganese stainless are:

1. No appreciable tonnages of low-nickel manganese stainless steels are currently being produced.

2. No insuperable difficulties are encountered in the production of these steels.

3. Most fabrication problems appear to have been resolved.

4. The performance of A.I.S.I. 201 and 202 in service, if properly applied, has been satisfactory. Type 201 seems to be entirely adequate as a substitute for 301. Type 202 may be considered an alternate steel for all 302 applications except those involving some types of chemical corrosion. There appear to be a few uses where this steel may be an acceptable alternate for 304.

The report states: "It is felt that 201 and 202 are steels of proven merit and that everything possible should be done to encourage their use."

For purposes of actual mobilization, there can be no question as to the desirability of using these steels as alternates for 301 and 302 in proper applications. Their properties are well established and no further investigations of this sort are needed. In arriving at these conclusions, Mr. Bennett presents a considerable volume of technical detail on basic metallurgy, mechanical and corrosion tests, production and fabrication practice, and service experience. The two essential differences are higher yield strength (about 10%) and slightly lower corrosion resistance of the 200 series.

As might be expected, Type 202 work hardens the least of the low-nickel manganese steel compositions due to maximum austenitic stability. It has forming properties about equivalent to 302 and should be used where deep drawing

Table II—Approximate Consumption by Industry of 18-8 Stainless

Industrial Classification	Consumption by Type, Net Tons			
	301	302	304	Total
Steel industry; maintenance, repair and operations	—	—	500	500
Oil and gas	—	—	550	550
Contractors' products	1,150	1,000	—	2,150
Automotive	4,000	3,000	9,000	16,000
Railroads	8,000	—	—	8,000
Shipbuilding	2,000	—	—	2,000
Aircraft	1,000	15,500	10,000	26,500
Chemical process industry	—	3,000	3,500	6,500
Food processing	—	2,000	5,750	7,750
General-purpose industrial	1,150	500	1,000	2,650
Special-purpose industrial	—	—	7,750	7,750
Electrical equipment	—	1,250	1,700	2,950
Domestic appliances	—	10,000	2,000	12,000
Commercial equipment	—	5,000	1,850	6,850
Military (except aircraft)	1,000	2,000	3,750	6,750
Unclassified	2,700	13,750	20,650	37,100
Totals	21,000	57,000	68,000	146,000
% of total stainless production*	3.4	9.3	11.3	24.0
% of 300 types†	8.4	22.9	27.3	58.6

*601,000 net tons of all types.
†250,000 net tons total production.

is necessary. Type 201 has annealed hardness values slightly higher than 301, but can be formed equally well under similar conditions.

The machinability of 201 is roughly comparable to that of 301 and 202 to 302. Welding appears to present no problems and the Budd Co. reports that all grades can be welded together interchangeably. No annealing is necessary after welding.

One of the major features of stainless steels is their resistance to corrosive attack. Both 201 and 202 show satisfactory resistance to atmospheric corrosion. The A.I.S.I. reports that the 200 series, while slightly less resistant to chemical corrosion than 301 and 302, would generally be considered as satisfactory alternates. Tests include boiling 65% nitric acid for 48 hr.; boiling 1% copper sulphate, 8% sulphuric acid for 72 hr.; 5% lactic acid for 96 hr. at 86° F.; 10% phosphoric acid at 86° F. for 96 hr.; 60% acetic acid for 96 hr. at 158° F.; and nonaerated 10% sulphuric acid at 158° F. In all except the last-named corrosive medium, no significant differences in resistance were observed.

Unlike nickel, manganese is an oxidizable element which raises certain problems as to scrap recovery in the steel mill. If stainless scrap is melted down at the beginning of a heat in the usual manner, both chromium and manganese will oxidize and go into the slag with resultant poor alloy recovery, while the nickel content will be practically unaffected. This places the manganese-type stainless steels in a somewhat unfavorable position as compared with the conventional austenitic compositions. It is possible in some mills to compensate substantially for the high manganese loss by back-charging all nickel-manganese scrap near the end of the reducing period. Bennett discusses this matter at some length and indicates a sequence of operations which can be expected to yield recoveries of 80 to 85% for manganese and 90% for chromium. If the manganese-type stainless scrap is melted down initially, recovery figures as low as 30% for manganese and 75% for chromium are not considered unusual.

A very recent development of considerable interest to industrial users of stainless steel is the fact that prices have been established by the mills for the new manganese-type stainless steels. These prices run 2¢ per lb. lower for 201 than 301, with the same differential between 202 and 302. This attractive saving to the industrial user suggests that the producing mills share with the Department of Defense an interest in furthering the exploitation by industry of the manganese-type stainless steels. Certainly price should be no impediment on these favorable terms.

The military measure of relative availability of materials under mobilization conditions is the Relative Scarcity List. In this system, materials and alloys are assigned numbers of "relative scarcity", the lower the number the more available being the material. The following tabulation gives the relative scarcity numbers for a representative group of stainless steels, including both conventional 18-8 Cr-Ni, and low-nickel manganese compositions.

Type	Relative Scarcity No.
304	3.0
302	2.8
301	2.5
202	2.4
201	2.2
430	1.5
410	1.1

These relative scarcity numbers are being applied increasingly by the military departments in specifying steels and in purchasing shelf-type items for military use.

Conclusion

Imports of nickel into the United States are increasing each year but our economy has been growing and the use of nickel-bearing alloys has been increasing at a more rapid rate than imports. No reversal of this trend seems likely to occur unless the industry itself takes the necessary action. Alloys are available to accomplish a major reduction in current uses of nickel. These alloys have been tested and found acceptable in performance. Price differentials should encourage their use. In easing the current nickel shortage by the use of these steels, the producing and consuming industries will at the same time be contributing in an important way to the national security of our country.

Naturally, the Department of Defense is not in a position to judge the commercial acceptability or economic feasibility of using manganese-type stainless steels in peacetime products for nonmilitary consumption, but enlarged use of this type of steel is manifestly of advantage to the Defense Department. The Military Services are being encouraged to take an interest in applying it to military designs. For this reason, the views of the Department of Defense are presented in this paper in the hope of stimulating a response by private industry now.

Factors Governing Induction Hardening of Steel Surfaces

*By HARRY B. OSBORN, JR.**

Curves on the Data Sheet, p. 104-B, summarize information taken from production records on several hundred jobs. All the steels had 0.45 or 0.50 average carbon; most were plain carbon steels. There was no time delay between heat and quench. Unless specified, size is 1¾-in. rounds. Surface hardness was C-63 to 65; "depth" means distance down to C-50. "Power density" is the relation between energy put into the inductor and the surface area hardened. Data for 500,000 cycles are also applicable to frequencies down to 375,000.

Static Hardening – If the part is closely coupled by the inductor and quenched in position, the width of the hardened area is always slightly less than the inductor, and the depth of hardness is greater at the center of the inductor width unless its face has been properly recessed.

Curves for minimum power density (Fig. 1) become asymptotic to zero as the diameter decreases, and to some definite value as diameter increases (assuming a certain depth of hardening). Thus, 10 kw. per sq.in. at 500,000 cycles suffices for bars of any size over 3 in. if depth needs be no greater than 0.050 in.

Power density versus heating time for 1¾-in. bars is shown in Fig. 3, and furnished a guide for any diameter. Slope of the graph on log-log paper is significant and indicates that 35 to 40 kw-sec. per sq.in. may be safely applied to a wide variety of analyses.

Prior structure (fineness of microconstituents) has an important influence on power requirements for surface hardening, as shown in Fig. 4. Note also that more power at 3000 cycles is required for the most favorable microstructure than at 10,000 cycles.

Progressive hardening is done by passing long parts through a closely coupled inductor and quenching the hot region just as it leaves the magnetic field. Quenching streams must be directed so no water sprays back into the inductor.

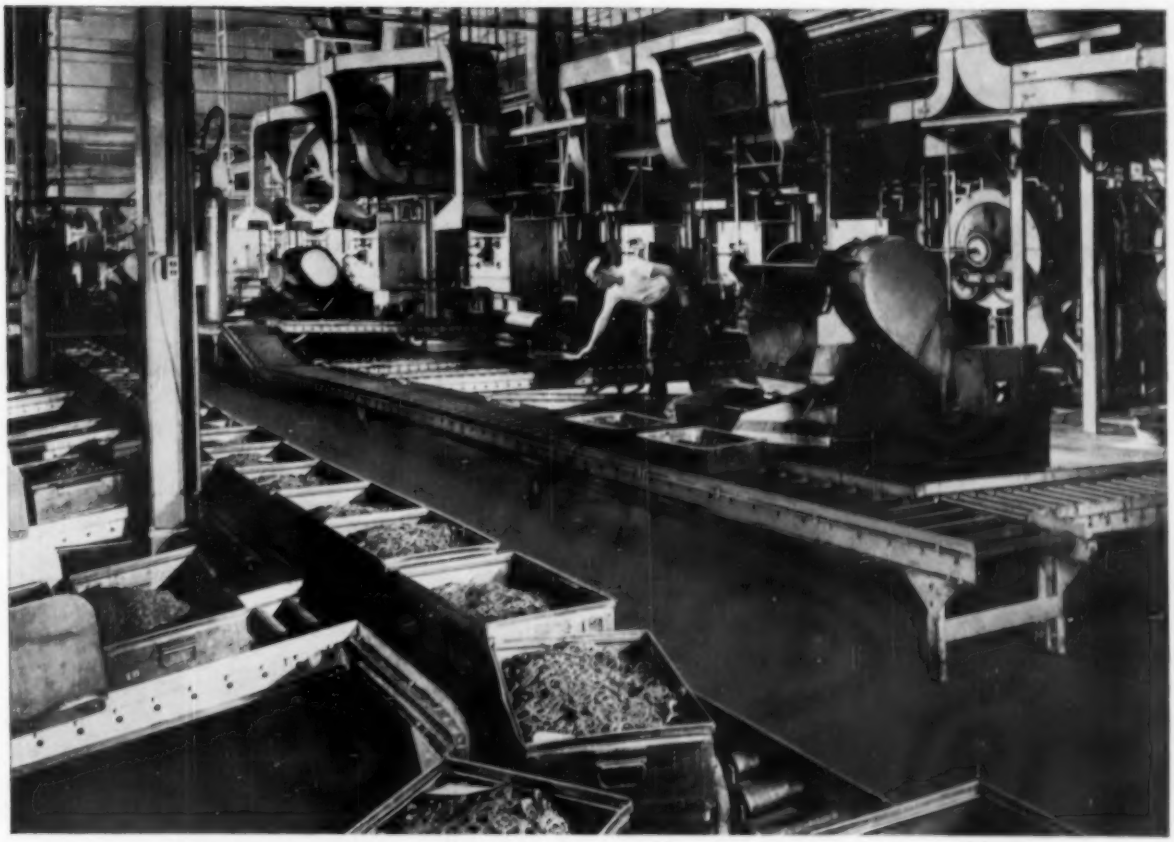
Even though the lines in Fig. 2 are drawn for 25 kw. per sq.in., depth of hardness is directly proportional to rate of travel at any practicable power density. All lines in Fig. 2 are straight and parallel. One point only is necessary to fix relationships for other conditions. Thus if a part is processed on a certain piece of equipment, it is only necessary to know the depth produced for a given rate of travel and a line can be drawn predicting depths for other processing speeds.

Correct power density for progressive hardening may be estimated from the straight line in Fig. 1, drawn from data from a wide variety of analyses and diameters from 0.5 to 3 in. The line is analogous to the one in Fig. 3 for static hardening, in that the required power density is less at slow rates of travel (longer times within the induction coil). Lines for 50 and 100 kw. per sq.in. in Fig. 5, plotted on log-log coordinates, show that increased power permits faster rate of travel for a given diameter. These relationships average data for A.I.S.I. 1045, 3140, 4130, and 52100 steels. With fixed power input to inductor (approximately ⅛ in. wide) the power density decreases with increase of diameter.

Figure 6 on the Data Sheet is similar to Fig. 5, but applies to 500,000-cycle current and shallower hardening (0.050 in.). The inductor is ¼ in. wide. Note difference in the scale of horizontal coordinates representing diameter, and differences in slope of lines for various power densities. Lines in either Fig. 5 or 6 can be used to predict processing speeds for different diameters by simply having one set of values of travel and diameter and drawing a line through this point parallel to those on the charts.

"Response" of the material must always be taken into consideration; adjustments from the control factors in the Data Sheet can be anticipated. However, these charts will speed up considerably the establishment of production cycles and eliminate a lot of "cutting and trying".

*Technical Director, Tocco Div., Ohio Crankshaft Co., Cleveland. Portion of paper presented before Industrial Heating Equipment Assoc. at National Metal Congress, Philadelphia, Oct. 19.



At low heat-hour cost . . . Nichrome muffles give thousands of hours of high temperature service in gas furnaces manufactured by the American Gas Furnaces Company, Elizabeth, N. J., in operation at plant of Shakeproof Div., Illinois Tool Works, Elgin, Ill.

Nichrome muffle . . . able to handle corrosive gas for 5½ years at 1600°F

HANDLING A CORROSIVE MIXTURE of city gas and ammonia, a Nichrome muffle used for heat treating small steel parts completed 36,732 hours of almost uninterrupted service at 1600°F.

But this temperature is no severe test for Nichrome. Even at higher temperatures, under normal heating conditions you'll find little deterioration of this 60% nickel-15% chromium-iron alloy.

Actually, the big story about a Nichrome muffle is its ability to withstand "thermal shock." Shock from repeated alternate heating and cooling. And shock from intermittent charging of cold work.

Naturally, the 60% nickel content in Nichrome produces significant effects. For one thing, it improves load-carrying characteristics at elevated temperatures. Equally important, the nickel addition plays a major role in improving resistance to scaling from common industrial atmospheres.

A typical nichrome muffle, produced by Driver-Harris Co., Harrison, N. J. Nichrome muffles of this type weigh from 291 to 2775 lbs., depending on furnace size and function.

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Surface Hardening by Induction

By Harry B. Osborn, Jr.

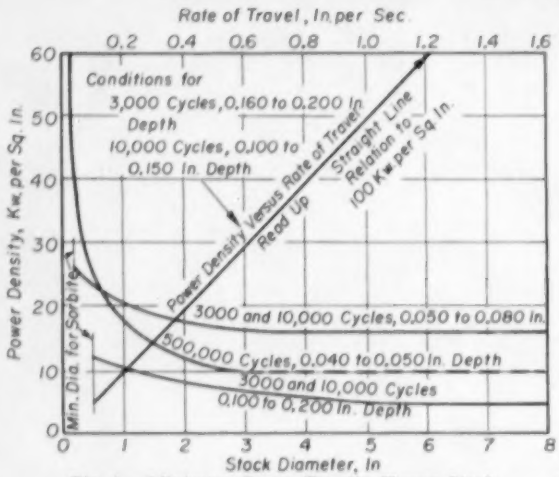
Rate of Travel, In. per Sec.
Power Density, Kw. per Sq. In.
Conditions for
3,000 Cycles, 0.160 to 0.200 In. Depth
10,000 Cycles, 0.100 to 0.150 In. Depth
Power Density Versus Rate of Travel Read Up
Straight Line Relation to 100 Kw. per Sq. In.
Min. Dia. for Sorbite
3000 and 10,000 Cycles, 0.050 to 0.080 In.
500,000 Cycles, 0.040 to 0.050 In. Depth
3000 and 10,000 Cycles 0.100 to 0.200 In. Depth
Stock Diameter, In

Fig. 1 — Minimum Power Density Versus Stock Diameter for Static Hardening, and Versus Rate of Travel for Progressive Hardening

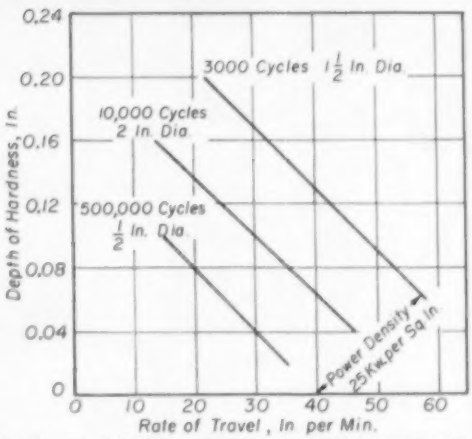
Depth of Hardness, In.
3000 Cycles 1½ In. Dia.
10,000 Cycles 2 In. Dia.
500,000 Cycles ½ In. Dia.
Power Density 25 Kw. per Sq. In.
Rate of Travel, In. per Min.

Fig. 2 — Straight-Line Relationships Between Depth of Hardness and Rate of Travel for Surface Hardening by Induction of Long Bars Progressively

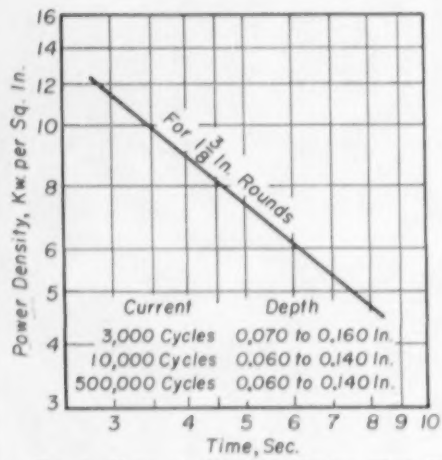
Power Density, Kw. per Sq. In.
For 1⅛ In. Rounds
Current Depth
3,000 Cycles 0.070 to 0.160 In.
10,000 Cycles 0.060 to 0.140 In.
500,000 Cycles 0.060 to 0.140 In.
Time, Sec.

Fig. 3—Slope of Graph Indicates That 35 to 40 Kw-Sec. per Sq. In. Is Correct Power Input for Static Hardening Most Steels

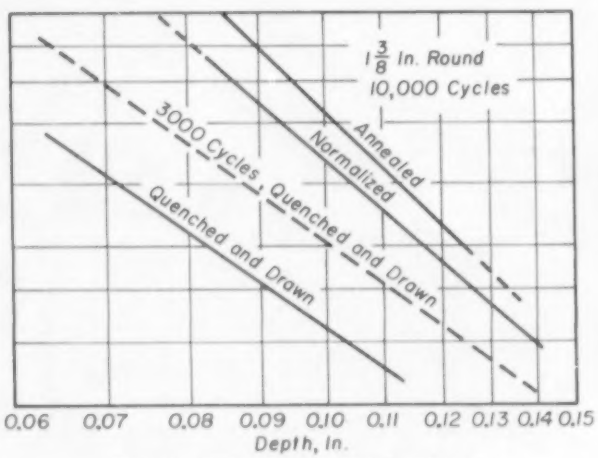

Fig. 4 — Influence of Prior Structure (Fineness of Microconstituents) on Power Requirements for Surface Hardening

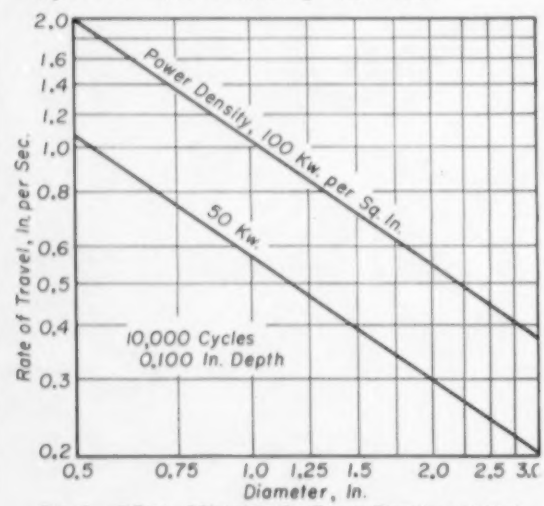

Fig. 5 — Effect of Varying the Power Density at 10,000 Cycles on Progressive Hardening 0.100 In. Deep

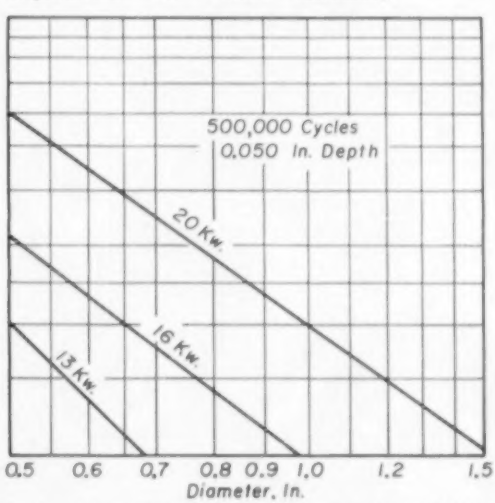

Fig. 6 — Effect of Varying the Power Density at 500,000 Cycles on Progressive Hardening 0.050 In. Deep

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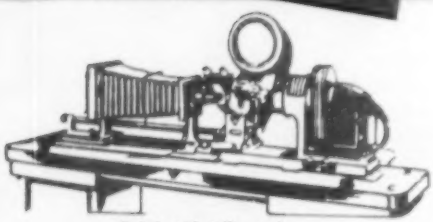

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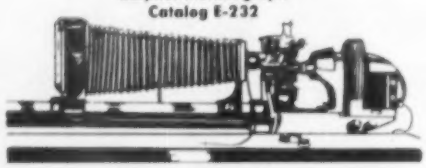

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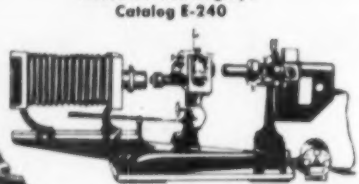

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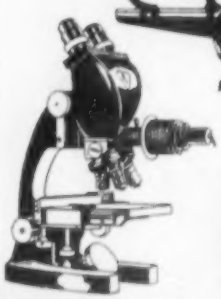

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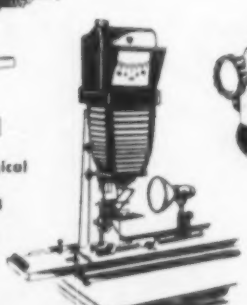

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Surface Hardening by Induction Heat

. . . Its Metallurgical Aspects

*By HARRY B. OSBORN, JR.**

The ability of induced electrical currents to generate heat in the surface layers of steel parts with unparalleled rapidity results in many manufacturing advantages and economies. The underlying metallurgy is expounded. (J 2)

FROM the almost overwhelming mass of material which could qualify as "Metallurgical Aspects of Induction Heating", this paper proposes to set forth some basic considerations and show how controllable variables such as frequency and power density affect the depth of hardness and microstructure of the heat treated part. Further to simplify the subject matter it will be limited to the surface hardening of a cylindrical steel part, primarily for producing a wear resistant surface but sometimes for other cogent reasons.

Heating – The typical cylinder is heated by the resistance it offers to electrical currents induced on the surface. The main variables governing the depth of hardening are the frequency of the alternating current, the diameter of the steel bar, and time. In order for a surface layer to be hardened it must obviously be heated above the critical temperature, and a certain amount of time – even though very short – is necessary for heat generated at the very surface to be conducted inward.

Much has been said and written about the desirable frequency to use. One thing to bear in mind in thinking about the surface hardening of solid rounds is that the minimum frequency is a function of the bar's diameter. Neglecting this factor of size, *depth* of penetration D of the induced electrical energy (the thickness of the conducting layer) is approximately defined by the equation $D = \sqrt{{}^{1}/_{F}}$ where F is frequency in cycles per sec. Solving the equation for various frequencies we have:

3,000 cycles	0.035 in. penetration
10,000 cycles	0.020 in. penetration
500,000 cycles	0.003 in. penetration

Several factors combine to make the minimum practical depth of penetration considerably above these theoretical figures. In the first place the formula applies for zero time. Obviously no metallurgical transformation can take place instantaneously, even though conduction of heat into the cold core is *very* rapid. This skin effect, or the tendency for the heat to be developed on the surface, assumes less and less significance as the heating time increases. The additional depth D′ which necessarily results from heat flow by conduction is

$$D' = \sqrt{0.0015\,T}$$

Where D′ is the depth in inches and T is the time in seconds.

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*Technical Director, Tocco Div., Ohio Crankshaft Co., Cleveland. Portions of a paper presented before the Industrial Heating Equipment Assoc. meeting at the National Metal Congress and Exposition, Philadelphia, Oct. 19, 1955.

Solving the equation for various times gives:

0.5 sec.	0.027 in. penetration
1.0 sec.	0.039 in. penetration
2.0 sec.	0.055 in. penetration

From the above two equations one can estimate the depth of hardness when using a given frequency and heating time. (Power density also enters the picture and its effect will be covered later in considerable detail.) Additional hardness depth (heat penetration) results from a delay between power shut-off and quench.

Quench – Where the part is reasonably large in cross section and the depth of hardness is not sharply limited, the delay time between heating and quenching is not extremely critical. It gives additional time at high temperature for solution and uniform diffusion of the metallurgical components without going to higher temperatures and is, therefore, quite advantageous. However, such delay periods are infrequently used since the temperatures can be run up in the short heating cycles generally associated with induction heating, thus obtaining the same results without undesirable coarsening of the microstructure. Good solution and diffusion are accomplished (if prior microstructure as outlined in the next section is correct) in time too short for noticeable grain growth in the austenite.

A long round can be surface hardened progressively, being heated as it goes through a relatively short induction coil and quenched as it emerges. If a limited amount of power is available, the long part may still be properly hardened to the required depth by introducing the power in a narrow inductor. In this instance, the depth of penetration is not a function of frequency but primarily of power density, and secondarily of the rate of travel through the inductor. This last-mentioned factor is comparable to time of heating in the "single shot" or "static" method, and the quenching practice, while not involving a delay time, does enter the picture as a controllable item. The metallurgist can vary the angle at which the quench holes are drilled, thereby controlling the distance between the end of the inductor (the point at which the part loses the effect of the high-frequency current) and the point at which it reaches the quench. Obviously, the longer the time interval between leaving the inductor and striking the quench, the greater the heat flow inward by conduction.

Delay between power shut-off and application of quenching jets assumes extreme significance

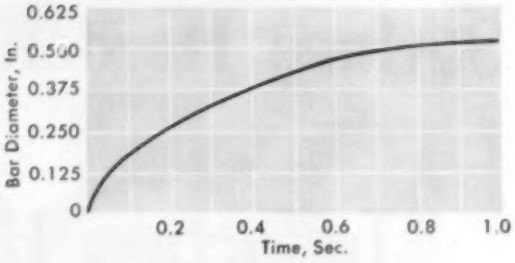


Fig. 1 – Relation Between Transient Thermal Time Between Power on and Quench, and Diameter of Round for Through Hardening

when surface hardening small-diameter rounds and thin-walled tubes. It is difficult to evaluate accurately the many variables involved, but for a given set of conditions there are certain minimum times to prevent through hardening. With surface temperature of 1650° F., theoretically maintained constant for zero depth, Fig. 1 plots this transient thermal time against diameter of solid bar. For example, if a ½-in. round is to be surface hardened, theoretically it must be quenched within 0.8 sec. or the heat conducted inward will harden the metal to the center.

Figure 1 plots a theoretical relationship and neglects the fact that there is a certain depth of metal at the 1650° F. surface temperature. Nor does it account for a drop in surface temperature during the delay before quenching. However, the two factors seem to offset each other, for the theoretical curve in Fig. 1 checks laboratory studies. Another large influence is played by prior microstructure – a matter to be discussed in the next section.

However, assuming chemical analyses and microstructure which respond readily to heat treatment, the *minimum* depths of hardened layers for parts in production are

Frequency	Minimum Depth in Practice
3,000 cycles	0.060 in.
10,000	0.040
500,000	0.020

These minimum practical depths are from two to seven times the theoretical as listed earlier in this paper, the difference being the greater as the frequency goes up.

Effect of Prior Microstructure

Given a certain set of dimensions and electrical conditions, another set of variables is vitally important. These refer to the chemical analysis of the steel but more especially its microstructure. These influence the result be-

cause the time at heat, during induction hardening, is very short and the carbides must be in such condition they will go rapidly into solution in the austenite (or at least an effective amount of them). Diffusion, once carbon is in solution, is exceedingly rapid when we consider the distances measured by fine grain in austenite. Fortunately, the inherently short heating time of induction heating permits the use of higher austenitizing temperatures than with furnace practices. This high temperature correspondingly speeds all the physical changes within the metal's structure.

It might be emphasized that there is nothing magical about induction heat in the sense that it will do anything more than the proper number of British thermal units will do if put into the steel correctly by a hot furnace atmosphere or a molten salt bath or in any other way. A Btu. is a Btu. Speed of heat generation in a definite area and depth, and generation in precisely controllable quantities are the prime reasons for using induced electrical currents for heat treatment of metal.

In view of the short heating cycles and therefore the short time the steel is above the critical, prior structure is very important. Coarse spheroids and coarse-grained ferrite must of necessity be heated hotter and longer than sorbite or fine pearlite.

Sometimes a compromise must be made with requirements in other directions. If the stock requires much machining, best structure for machinability very often is undesirable for induction heating. Ordinarily this merely involves adjusting power (surface temperature) and time within the coil (time at heat). Only in the event that hardening depth is strictly limited does a coarse structure cause difficulty in heat treating.

It is always desirable to induce the minimum temperature which will produce the necessary hardness and correct microstructure. What this temperature is usually depends upon other conditions than the analysis of the material. Possibly surface temperature is of most importance when hardening the plain carbon steels – the lower the carbon content the higher the temperature needed. We could plot temperature against carbon content and have practically a straight-line function as far as 0.45% carbon, when we reach a minimum temperature. Additional carbon content has no effect on the ease of obtaining full hardness; the excess carbon may not be completely in solution, yet may not be necessary for wear resistance. Undissolved carbide particles may be very helpful.

It results that normalized 1090 steel austenitizes very rapidly at moderate temperatures a little above the eutectoid. From what already has been said it follows that low-carbon steels respond better if they have been previously heat treated to a sorbitic microstructure. Carbide particles in higher alloy steels are often complex in chemical composition, and dissolve more slowly than plain cementite. Steels with such microconstituents must also be either heated higher or be longer at heat than simpler steels.

Metallographic examination and hardness surveys are of course the simplest and best ways of determining the over-all results. Structure not completely in solution must be given higher temperature or longer heating time, or both. If depth may be increased, then longer heating time will usually suffice. To meet hardness-depth specifications, longer heating must sometimes be done at a reduced power imput.

If micro-examination indicates overheating, power or heating time or both must be reduced – always remembering the basic rule that high power at a given frequency for a short time produces shallow depths, and lower power for a longer time produces greater depths. The various effects of power, time and frequency are covered in a series of curves on p. 104-B.

The extraordinary rapidity of carbide solution and carbon diffusion has already been mentioned. This is proven qualitatively by the common observation that microstructure of hardened plain carbon steels heated no more than 0.2 or 0.3 sec. shows no free ferrite or residual carbide particles. Even complex alloy steels show fully martensitic hardened areas free from carbides if the prior structure contained no coarse particles and if the hardening temperature is boosted a couple of hundred degrees.

Quenching – When the proper frequency, power and heat time are applied, only half the job is done. Once we have obtained homogeneous austenite we must convert it to martensite by a suitable quench. While the selection of quench is sometimes determined by the type of steel, induction hardening does not differentiate between "oil hardening", "air hardening" and "water hardening" steels. Regardless of the steel's hardenability, if the part is uniform in shape, with no stress-raising areas – as, for example, a plain round bar – water jets can always be used. The physical configuration sometimes dictates the need for a milder quench with soluble

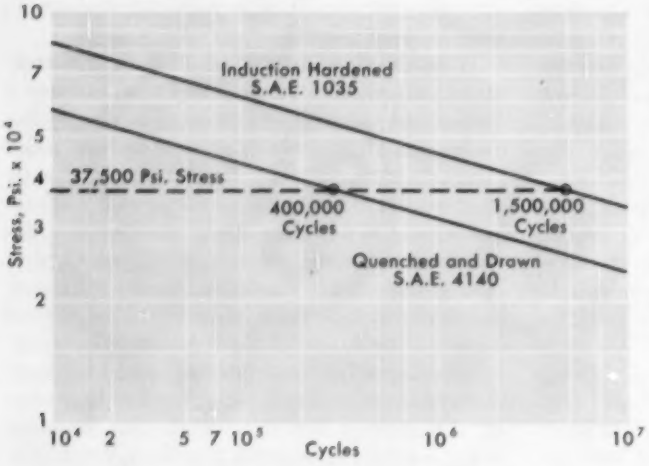


Fig. 2 – Torsional Fatigue Tests, Full Size, on Automotive Shafts From Production. Induction hardened to C-55 to C-58, no draw. Data are from Dana Corp., Ft. Wayne Div.

oil or regular quenching oil; S.A.E. 1050 gears are often oil quenched for that reason.

All quenching must be at sufficient speed to exceed the critical cooling rate of steel by a safe margin. Under normal conditions this always will prevail; otherwise the volume and pressure of the streams must be increased. The quench must last long enough to bring the part down through the martensite transformation range.

Quenching for surface hardening is always by direct sprays through the inductor or directly beyond it if the part is treated progressively. Quenching jets assure greater uniformity than with any other technique.

Preheating – Sometimes the heating cycle is divided so that the part is mildly heated throughout before it is superficially heated for surface hardening. This has two advantages. The first is that a smaller amount of high-frequency energy is necessary; either less power or shorter heating time is required. Secondly, the hot core stress-relieves the hardened case immediately following the quench. Preheating may be done in the same fixture used for the subsequent induction heat treatment simply by switching on current at low power at first and permitting the heat to flow inward by conduction for a considerable time. Then, by program control, full power is switched on long enough to austenitize the surface. Alternatively, a dual fixture, the first with low-frequency 60-cycle power heating may be used – likewise conventional fuel-fired furnaces.

Superhardness – Slight reference must be made to "superhardness". Inspection of parts in the production line shows that surfaces hardened by induction have Rockwell numbers slightly higher than those normally attributed to the carbon in the analysis. Maximum hardness obtainable in ¾-in. cubes, heated 50° F. above the upper critical and quenched in iced brine, is two or three points below the hardness of induction hardened parts. This is true for the complete carbon range for both plain and alloy steels and for cast iron.

Superhardness is considered by the present author to be of academic importance only. It is a phenomenon probably associated both with the short heating cycles and with the rapid quenching. Sometimes the observed hardness drops off slightly for several days, but eventually stabilizes at values measurably in excess of the maximums normally expected. This suggests that the superhardness may be due to high compressive stresses in the surface which may gradually be relieved. However, cast iron *increases* in hardness after the parts are processed.

Surface Hardening for Other Purposes

Improved Fatigue Life – Surface hardening to fairly great depths of long bars as they progress through an induction coil and quench has been found to improve the fatigue life of parts made therefrom. Furthermore, this has enabled the metallurgist to substitute plain low-carbon steels for previously used alloy steels, not only with large savings in costs of material and machining, but also with an increase in

Fig. 3 – Sectioned Roller for Sprague Race Showing Ring Deep Hardened to Carry Very Heavy Loads

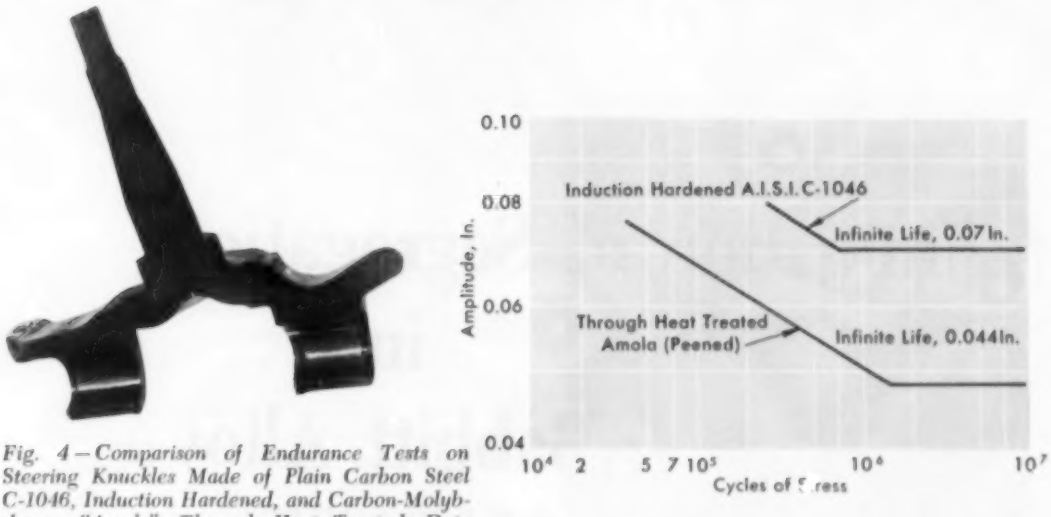


Fig. 4 – Comparison of Endurance Tests on Steering Knuckles Made of Plain Carbon Steel C-1046, Induction Hardened, and Carbon-Molybdenum "Amola", Through Heat Treated. Data from Chrysler Corp. Photograph is a sectioned knuckle showing localized hardened region

fatigue life in both torsion and bending of as much as 200%. This has been used very successfully for automobile axle shafts – saving up to 45¢ per shaft.

The process consists of continuously surface hardening at a power input which will result in relatively deep heating. Therefore, frequencies of 3000 or 10,000 cycles are used. The traverse rate is about ¼ in. per sec. The taper of the finished shafts presents no problem. Total depths heated run from 0.200 to 0.250 in. Minimum specified depth of hardness (depth to 50% martensite) is from 0.120 to 0.160 in., depending upon diameter.

Figure 2, from data supplied by Dana Corp., shows the improvement in torsional fatigue life of an induction hardened S.A.E. 1035 drive shaft as compared with a deep hardened, quenched and drawn S.A.E. 4140 shaft. The alloy shafts endured only 400,000 cycles and the induction hardened 1,500,000 at a repetitive impact of 612 ft-lb., causing 37,500 psi. maximum stress. Similar results were found by Chrysler Corp., when testing axle shafts in bending fatigue. Induction hardened S.A.E. 1037 steel had infinite life at a maximum stress of 60,000 psi., whereas through heat treated, quenched and drawn carbon-molybdenum "Amola" steel (peened) could endure only 38,000 psi. indefinitely.

The full hardness of induction hardened parts is sometimes drawn back so that the surface hardness, averaging originally about Rockwell C-55, is reduced to about C-48 to 50. This may be done in a fuel-fired furnace at approximately 500° F. or on the return travel through the inductor block during which high-frequency power and low power density does the heating. Ten million shafts have been so processed.

Back-Up for Heavy Bearing Loads – Very often a wear resistant surface is subjected to heavy pressures. Ordinary shallow carburized cases will not support such loads. Increasing such case depth to, say, 0.100 to 0.150 in. would be extremely costly. A good example of this is a Sprague race which carries a heavy load by "locked" rollers (Fig. 3). The steel is S.A.E. 5160.

Critically Stressed Areas – Selective hardening a critically stressed area has proved to be a very effective way of increasing the endurance limit of the part. Fortunately this can be done and at the same time an additional advantage is gained by switching from alloy to carbon steel.

For example, a steering knuckle is called upon to do an important job on a vehicle, and selective surface hardening, as shown in Fig. 4, increases the endurance limit tremendously, insuring a far greater factor of safety. The alloy shaft could endure indefinitely a strain of 0.044-in. amplitude, whereas the induction hardened shaft could endure 0.070 in.

Enough has been said to indicate clearly that rapid surface heating by induced electrical currents causes the same changes in microstructure and mechanical properties of the steel as the same heat from any source would effect – *provided* the heat could be generated so rapidly and under such close control. This article tries to show metallurgical engineers how the product can be kept under close control and why the proven advantages do accrue to the machine parts and tools hardened in this way. A supplementary short article and data sheet on p. 104 and 104-B present some specific relationships, drawn from practice, among the various controllable factors.

Elimination of Segregation in Babbitt Alloy

*By W. J. REICHENECKER**

Copper additions of about 0.7% markedly reduce the tendency toward segregation in lead-tin-antimony babbitt alloys and result in more uniform cast structure of heavy bearings. (Pb, SG-c)

SEGREGATION is often encountered in bearings cast from lead-base babbitt alloys containing tin and antimony, particularly when cooling rates are slow. Segregation can be eliminated by increasing the cooling rate so that the alloy freezes before the constituents separate. Because of size or design of the bearing shell, however, it is not always possible to cool the bearing rapidly enough, and another method of controlling segregation is desirable.

The lead-base babbitt used for bearings manufactured by Westinghouse has a nominal composition of 8% tin, 14% antimony and 78% lead. Normally the copper content is limited to a maximum of 0.5%. It was decided, however, to determine whether copper additions would offer a means of satisfactorily minimizing segregation. Literature references indicate that copper is effective in reducing segregation in lead-base babbitt but may cause "frothing" during casting of alloys with low tin contents.

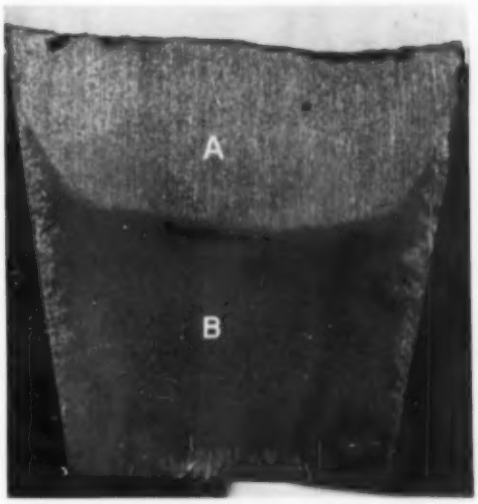
Three ingots weighing approximately 5 lb. each were poured from melts of the lead-base babbitt alloy which contained approximately 0.0, 0.4 and 0.7% copper. The molten babbitt was cast at 840° F. into an iron mold preheated to 620° F. The ingots were allowed to cool in still air so that any tendency toward segregation would be accentuated. The slow cooling rate approximates cooling conditions which occur when heavy-walled cast iron bearing shells are babbitted.

When the ingots had cooled to room temperature, they were stripped from the mold, sectioned vertically, ground smooth and macro-etched to reveal the structure. Photographs of these ingot cross sections are shown in Fig. 1, 2 and 3, together with the chemical composition of samples taken from the top and bottom section of each.

The pronounced effect of increasing the copper content on reducing segregation in this lead-tin-antimony babbitt alloy is obvious. Ingot 1 contained less than 0.03% copper and exhibits almost complete segregation of the tin-antimony constituent. With about 0.4% copper as in Ingot 2, segregation decreases and the distribution of the tin-antimony constituent is more uniform. Ingot 3, containing about 0.7% copper, is essentially free of any tendency toward segregation.

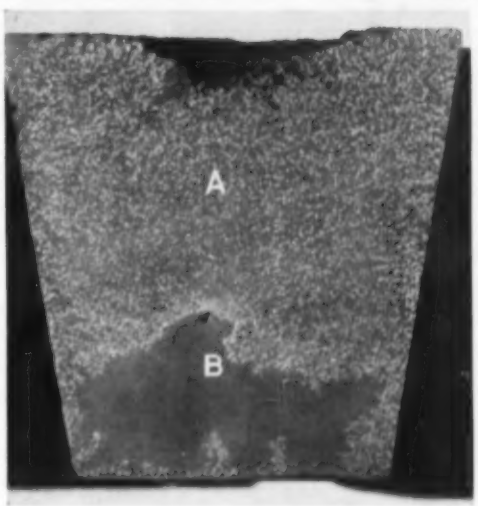
Based on the results obtained on the laboratory samples it appears that the addition of copper within the range 0.5 to 0.8% to this lead-base babbitt alloy offers a means of reducing segregation in cast bearings. Trial use of the copper-modified alloy in the shop yielded satisfactory results and a new material has been adopted for regular use in place of the essentially copper-free alloy previously used.

*Materials Engineering Dept., Westinghouse Electric Corp., East Pittsburgh, Pa.



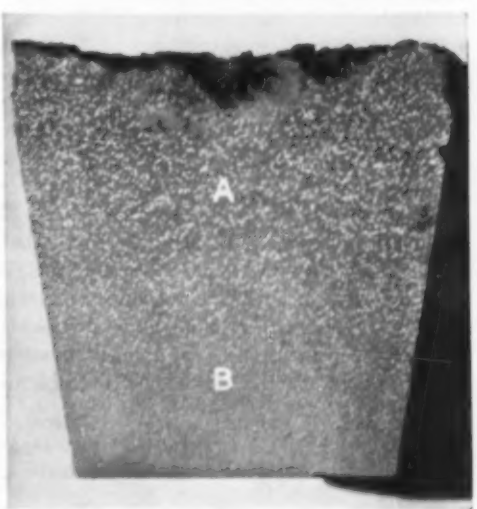
	Cu	Sn	Sb	Pb
Nominal composition	0.03	8.26	16.60	75.11
Location A	0.03	9.91	20.21	69.87
Location B	0.03	5.58	12.69	81.72

Fig. 1 – Extreme Segregation in Ingot 1 With Low Copper



	Cu	Sn	Sb	Pb
Nominal composition	0.38	8.13	14.34	77.15
Location A	0.60	7.36	13.39	78.65
Location B	0.24	7.13	13.12	79.51

Fig. 2 – Segregation Reduced by Intermediate Copper Content in Ingot 2



	Cu	Sn	Sb	Pb
Nominal composition	0.71	7.33	13.28	78.68
Location A	0.71	7.01	12.89	79.39
Location B	0.63	7.00	13.09	79.18

Fig. 3 – Segregation Practically Eliminated by 0.7% Copper

Toughness Without Tempering

By ROBERT H. ABORN*

The high toughness of quench hardened low-carbon steels is associated with high-temperature formation of martensite and subsequent tempering that occurs during quenching. (N 8, CN)

MARTENSITE has long been regarded with mixed emotions by metals engineers responsible for selection and processing steels for critical applications. When untempered it is so brittle and susceptible to cracking that fear of its presence has automatically ruled out the use of quenching in the manufacture of such things as pressure vessels. Yet when martensite is properly tempered, it provides the best combination of shock toughness and strength. Medium-carbon steels, so treated, have been used to meet the ultra high strength and ductility requirements of aircraft.

More recently a new class of steels has been developed which combines strengths up to 200,000 psi. with toughness, weldability and formability. Carbon content is limited to a maximum of 0.20% and Fig. 1 indicates the toughness obtainable with these untempered "low-carbon martensites" even at a hardness of Vickers 400 (about Rockwell C-41). Subsize specimens were used because A.I.S.I. 1013 will not harden completely through sections greater than about 0.1 in. thick but the boxed numbers 30 and 15 indicate the equivalent 30 and 15-ft-lb. energy levels for standard Charpy V-notch specimens. The remarkable toughness of such steels has led to the first limited use of quenched and tempered steel in pressure vessels. Low-carbon martensite is not raw and untempered as its high-carbon brother, but has, in a sense, been automatically conditioned, to set the stage for a favorable combination of maximum advantages with minimum disadvantages. We have studied its behavior with A.I.S.I. 1013, alloy steels such as 4315 and 43 BV 12, and even unstable stainless steels like Type 301. Although we don't fully understand the basic fundamentals we can now correlate the properties with microstructure.

Much of the work has been done with 1013 and three conditions of martensite were studied: *untempered; low-tempered* (1 hr. at 400° F.), corresponding to the treatment of the core of many carburized parts; and *high-tempered* to a nominal hardness level of C-29, corresponding to about 100,000-psi. yield strength – a level of increasing interest for readily welded, high-strength structures. The curves in Fig. 2 show that the untempered martensite is tougher than the same martensite after a low temper. Actually, plain low-carbon untempered martensite, even though born of large-grained austenite, has an equivalent 15 ft-lb. transition temperature at −140° F. Furthermore, as would be expected, the high-tempered martensite has the highest notch toughness – equivalent to a 30 ft-lb. level at −100° F.

The high notch toughness and ductility of low-carbon martensite can be traced to the fact that the temperature range in which austenite transforms to martensite during quenching is more dependent upon carbon content than upon any other solute element. In low-carbon steels this range is much higher than the corresponding range for medium and high-carbon steels. This temperature range of martensite formation is shown in Fig. 3 for 1013 and for 4315. Martensite formation begins in 1013 at about 870° F. and is

*Director of Fundamental Research Laboratory, U.S. Steel Corp. Kearny, N. J. This article summarizes portions of the 1955 Campbell Memorial Lecture, "Low-Carbon Martensites".

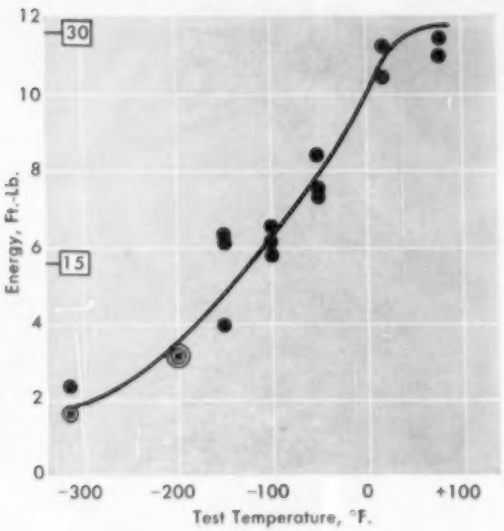


Fig. 1 – Notch Toughness of Untempered A.I.S.I. 1013 Martensite Measured on ¼-Size V-Notch Charpy Specimens

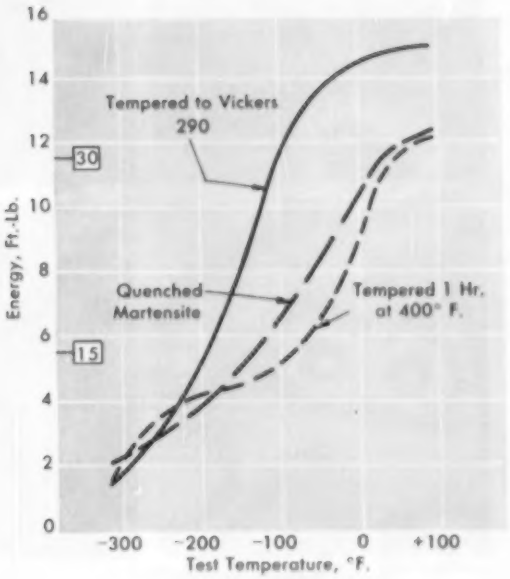


Fig. 2 – Effect of Tempering on the Notch Toughness of Martensite in A.I.S.I. 1013

completed at 735° F. just below the starting temperature in 4315. However, even in 4315, martensite formation is completed at a temperature above that at which it begins to form in most medium-carbon, low-alloy steels.

The idealized cooling curves for the center zone of specimens 1/32 in., ⅛ in. and 0.4 in. thick demonstrate that the first-formed martensite may be exposed to temperatures above 600° F. for periods ranging from about 1/6 sec. for the thinnest, to ½ sec. for the thickest section.

Although martensite is the only transformation product formed in any of these specimens on quenching, the hardness values reveal definite softening with increased section thickness in both steels, amounting to nearly 40 Vickers units in 4315 (Vickers 473 for 1/32-in. specimens versus 437 for 0.4-in. specimens).

In contrast to high-carbon steels, untransformed or retained austenite is insignificant in these quench hardened low-carbon steels. Repeated X-ray checks show that the amount of retained austenite present in these low-carbon martensites was always less than 0.5%.

Both 1013 and 4315 steels in various quenched and tempered conditions have been examined with both light and electron metallographic techniques. To avoid tempering during preparation all specimens were mounted either in metal clamps or in cold-setting plastic, and were wet ground to mid-thickness on lead laps.

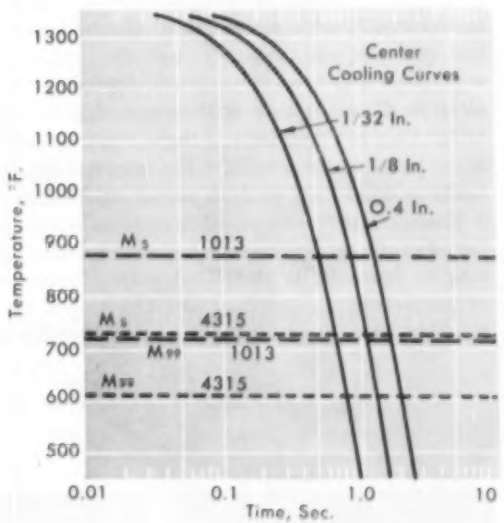
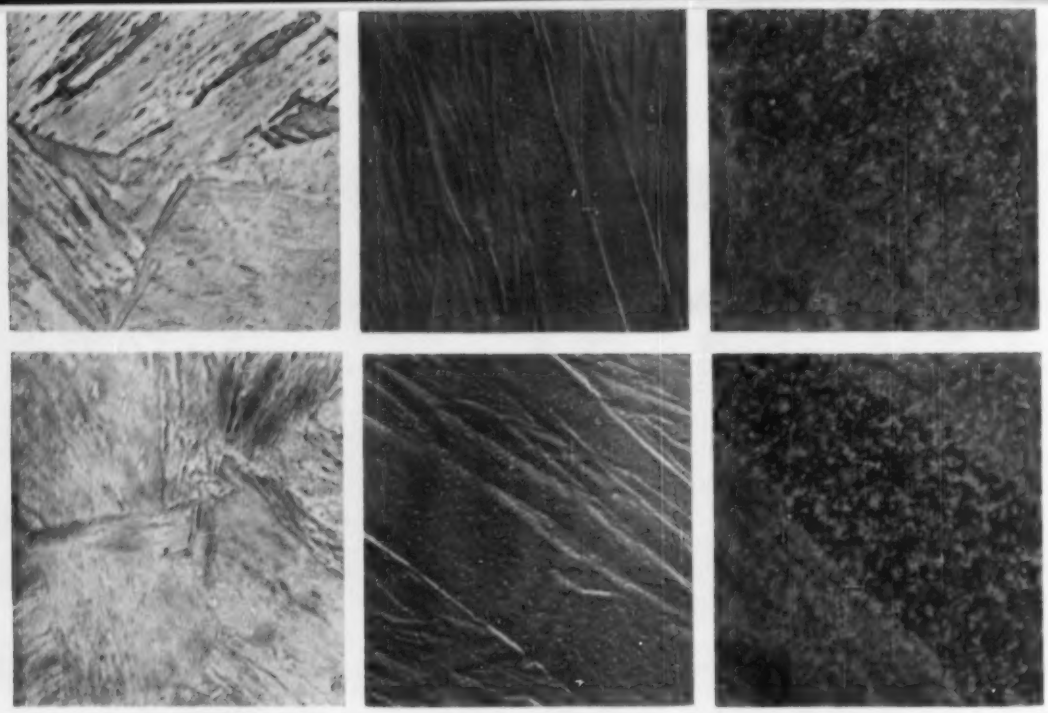


Fig. 3 – Temperature Range of Martensite Formation in A.I.S.I. 1013 and 4315 and Center Cooling Curves for Three Sections

Two different replica methods were used in preparing the electron micrographs. Those micrographs designated "shadow" in Fig 4 were taken of conventional uranium-shadow-cast plastic impressions of surface relief on the etched specimen. The other micrographs, marked "extraction", at right in Fig 4, were prepared



Light; 1300 × *Shadow; 7000 ×* *Extraction; 13,000 ×*

Fig. 4 – Microstructure of A.I.S.I. 1013 Martensite Quenched in Iced Brine From 2200° F. Picral etch. Top three are 1/32-in. specimens (Vickers 425); bottom three are 1/8-in. specimens (Vickers 405)

by a relatively new method, in which fine precipitate particles are stripped from the specimen with the replica, and examined directly in the electron microscope. Since the actual particles, rather than mere replicas of them, are examined, it is possible to identify the precipitate by electron diffraction analysis of selected areas.

These micrographs of 1013 martensite reveal that the effect of thickness and thus of cooling rate on hardness is associated with differences in microstructural appearance. The upper row are light, shadow and extraction micrographs of 1/32-in. specimens (Vickers 425), whereas the lower row are corresponding micrographs of ⅛-in. specimens (Vickers 405). In the light micrographs, some martensite plates in the thicker sample appear slightly darker than the matrix. The shadow micrographs, in the center, show more difference with an indication of some precipitation in occasional martensite plates in the ⅛-in. specimen. However, the extraction micrographs show that precipitation of very fine particles actually has occurred in some martensite plates in both samples. Such plates are consider-

Fig. 5 – Duplication of Quenched Structure by Tempering. Picral etch. 14,000 ×

1/8-In. Specimen, Quenched Vickers 405 *1/32-In., 2 Sec. at 600° F. Vickers 403* *1/32-In., 2 Sec. at 650° F. Vickers 393*

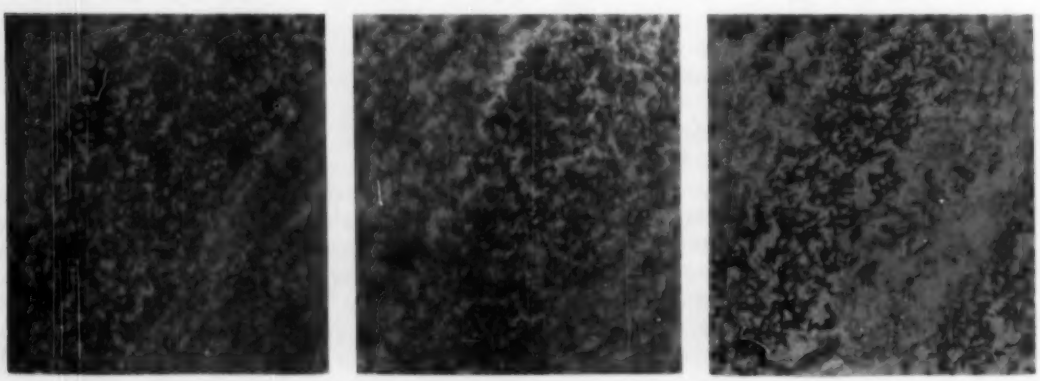


Fig. 6 – Minute Cementite "Straws" Formed on Q-Tempering. 50,000 ×

ably more common in the thicker sample which contains larger and more numerous particles. No precipitate was found near the more rapidly cooled surface of the thin specimen. The individual particles within the broad diagonal bands across both micrographs on the right may not be apparent because even the largest is only a few millionths of an inch in length. These particles, similar in shape to thin paper matches, are termed "straws" from their jumbled jackstraw appearance in the extraction micrographs. They have been identified by electron diffraction as cementite in these and many similar specimens. It should also be noted that the remainder of the martensitic matrix gives a mottled pattern.

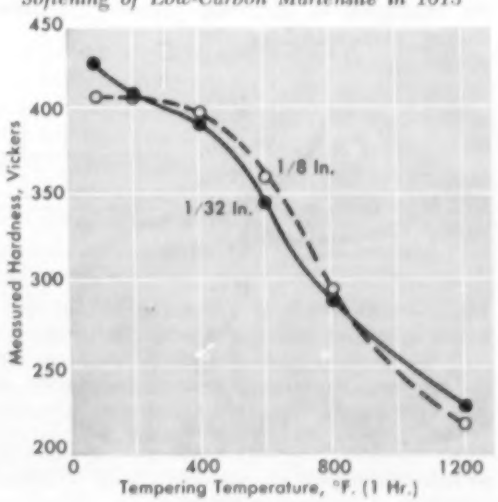
The microstructure and the hardness of the thicker specimen of 1013 martensite can be nearly duplicated by a very brief (2-sec.) tempering at 600° F. of the thinner quenched section as shown in Fig. 5. The sample tempered briefly at 650° F. shows larger and more numerous particles with scarcely any precipitation in the mottled background. Thus it is clear that decreasing hardness, and increasing alteration of the structure, with increasing thickness of low-carbon martensite, are due to an unavoidable tempering during quenching.

This form of tempering we call quench tempering, or, more briefly, Q-tempering, since it occurs during the same quenching operation in which low-carbon martensite forms. It produces a mottling of the martensitic matrix and a fine precipitate of minute cementite straws in certain plates, as shown in Fig. 6. The extent to which Q-tempering can occur depends both on the temperature at which martensite forms, and its subsequent cooling rate. By retarding the cooling rate during quenching of certain low-carbon, low-alloy steels, we have increased the extent of Q-tempered "straw" zones in the martensite to as much as 50%. Slower cooling rates of larger sections resulted in transformation products other than martensite.

The straw-laden zones are believed to represent the first-formed martensite plates which Q-tempered to cementite platelets in supersaturated ferrite. The mottled material from the surrounding martensitic matrix gives no crystalline diffraction pattern so it might be regarded as carbon soot formed during etching. However, its characteristic micrographic pattern, and the fact that it has not been found on etched retained austenite or high-carbon martensite, suggest that it may represent aggregates of pre-precipitation clusters of carbon, which form in the low-carbon martensite during quenching, and are caught on the extraction replica. It is not possible to resolve the individual clusters with present techniques.

Lowering the range of martensite formation by addition of alloying elements reduces the amount of Q-tempering for a given cooling rate; thus, for the same thickness, the extent of Q-tempering is less in 4315 than in 1013 martensite. There is no evidence of Q-temper "straws" in a 1/32-in. sample but only a mottled structure similar to the matrix of the corresponding 1013 sample. However, Q-tempered straws do form in this steel if the cooling rate is sufficiently slow. This Q-tem-

Fig. 7 – Quench-Temper and Applied Temper Softening of Low-Carbon Martensite in 1013



pering reaction has been observed in other low-carbon alloy steels and it seems certain that, except for extremely thin sections of high-alloy steels, this effect conditions the microstructure and the properties of low-carbon martensites. However, before discussing the dependence of some mechanical properties on Q-tempering, it will be helpful to examine the effects of deliberate or applied tempering by reheating these Q-tempered low-carbon martensites as shown in Fig. 7.

The original difference in hardness, due to the relative amount of Q-tempering, is evident at the upper end of the curve. The extent of softening below 400° F. diminishes as the section thickens, and the original hardness difference almost disappears after a tempering treatment of 1 hr. at 400° F. or above. We have found no appreciable change in the Q-tempered structure during a 1-hr. temper at 212° F., and 1 hr. at 300° F. causes only slight growth of straw particles. However, there is considerable growth of straws and extent of the straw zones during 1-hr. treatment at 400° F. Although the mottled matrix did not change much in general appearance, a detailed examination of these areas revealed the presence of an occasional stubby particle.

After tempering at 450° F., the mottled regions contain numerous particles, which are slightly broader and less match-like than the straws. This change is found to be more pronounced after tempering at 500° F., and at 600° F. the mottled structure has been wholly replaced by an aggregate of clustered stubby particles. Like the straw particles, all of the stubby particles were found to be cementite. The diffraction pattern obtained from both types corresponded to that of platelet, or predominantly two-dimensional cementite. We have found no evidence for epsilon carbide formation during tempering of any of the low-carbon martensites investigated.

Figure 8 summarizes and contrasts the mechanism of tempering of low-carbon steels and shows the basic differences. When high-carbon eutectoid austenite is quenched, martensite forms in the relatively low temperature range of 400 to 200° F. When this high-carbon martensite is reheated to successively higher temperatures, it decomposes first into epsilon carbide and secondary martensite containing about 0.25% carbon. In the second stage, retained austenite transforms to bainite. In the third stage epsilon carbide dissolves and cementite forms and the secondary martensite gradually becomes ferrite.

The temperature ranges of the several stages are actually not sharply separated, as indicated for simplified handling, but overlap each other. As shown here they are based on 1 hr. at the tempering temperature. Now, in contrast to the high-carbon sequence, when we quench low-carbon 1013 austenite, martensite begins to form at about 870° F. and is automatically Q-tempered. This Q-tempering occurring in low-carbon martensites during quenching appears to

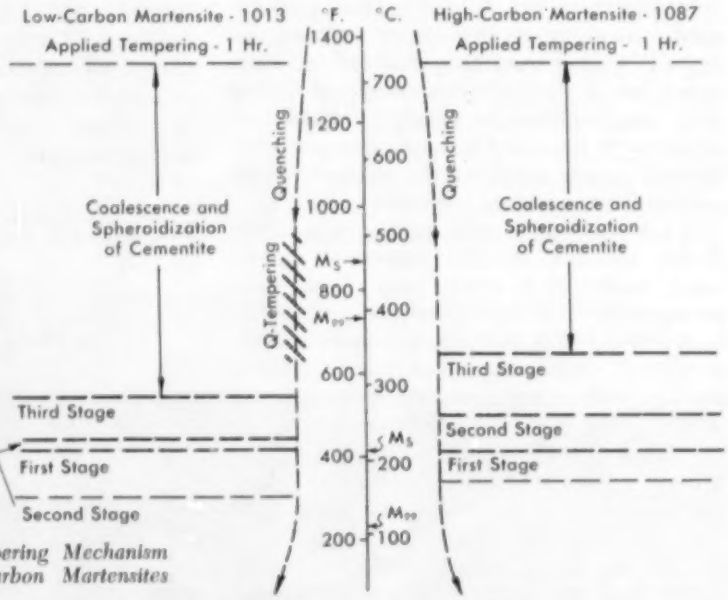


Fig. 8 — Comparison of Tempering Mechanism of Low-Carbon and High-Carbon Martensites

Tempering stages for low-carbon martensite, at left: First Stage — Growth of Q-tempered cementite "straw" particles and appearances of new "straw" Zones. Second Stage — Transformation of retained austenite; negligible amount. Third Stage — General formation of cementite platelets

Tempering stages for high-carbon martensite, at right: First Stage — Formation of epsilon carbide and secondary 0.25% C martensite. Second Stage — Transformation of retained austenite. Third Stage — Dissolution of epsilon carbide; formation of cementite platelets; disappearance of secondary martensite

have a profound influence on the course of applied tempering up to about 600° F.

Q-tempering has nucleated cementite and no epsilon carbide is formed. In the first stage of applied tempering, the Q-tempered cementite straws grow and new straw zones appear. The extent of retained austenite is negligible so the second stage can be neglected. In the third stage, cementite platelets are formed throughout the Q-tempered mottled matrix.

When carbide-forming alloying elements are added to low-carbon steels, indirect evidence suggests that the Q-tempered straw zones may be the sites of cementite particles which become enriched in alloy and remain relatively small even during prolonged tempering near the A_1 temperature. This characteristic may well account, at least in part, for the easy weldability of such heat treated low-carbon steels, for these more stable carbide particles dissolve less rapidly during the extremely brief weld heating.

Correlation With Mechanical Properties

This interpretation of the microstructure of low-carbon martensites enables us to correlate those features with some salient characteristics of the mechanical properties. The extent of ferritic cementite straw zone formation during Q-tempering, and its growth in the first stage of applied tempering, closely parallels the softening curve. Thicker sections have a greater degree of Q-temper softening, and less impetus for additional softening on applied tempering up to 400° F. The disappearance of mottling during third-stage tempering at 450 to 550° F. corresponds to the rapid softening of all sections.

The high notch-toughness of low-carbon martensites is believed to be a consequence of Q-tempering of the martensitic matrix, evident in the mottled structure. On this basis, the relative changes of notch toughness on applied tempering up to 400° F. are associated with still invisible changes in the mottled matrix.

Above 400° F. the story changes. Just as the incipient stage of general cementite formation is associated with diminished notch toughness in higher carbon martensites, so it is in these low-carbon martensites. When reheated in this 500 to 600° F. range, the third stage of tempering – namely, formation of cementite platelets – becomes detectable throughout the matrix and mottling disappears. These two circumstances may well set the stage for decreased resistance to plastic flow and increased susceptibility to crack formation and propagation.

One more set of unusual characteristics in mechanical properties remains for correlation. The very marked rise in yield strength or flow resistance observed in low-carbon martensites, without significant change in tensile strength on tempering at 400° F., has commonly been associated with relief of internal stresses. However, yield stress is very structure-sensitive; that is, its value is greatly affected by the presence of foreign atoms, precipitates, and grain boundaries because these obstruct the movement of imperfections or dislocations through each grain under applied load.

If the mottling of the Q-tempered martensitic matrix represents a very early stage of precipitation in which aggregates of atom clusters are beginning to form, then a low applied tempering, as in the first-stage zone, may promote this aggregation and obstruct slip more effectively. When such a structure is subjected to increasing applied load, the free movement of dislocations along favored slip planes in the lattice is obstructed successively by these atom cluster aggregates, so the yield stress is raised, and no sudden yielding occurs. This does not entail any significant change in ductility or tensile strength, each of which is measured after severe plastic deformation has taken place.

With further tempering, as in the third-stage zone, coalescence of the clustered aggregates, leading to the general formation of detectable cementite platelets throughout the matrix, will increase the mean free path for unobstructed dislocation movements so much that flow resistance will begin to fall.

Other Examples of Low-Carbon Alloy Martensites

Although we have emphasized the 1013 martensite this survey would be like a Gallup presidential poll confined to Maine, if we did not mention briefly a few of the many other low-carbon martensites which are far more prominent.

Constructional Alloy Steels – Several low-carbon steels with multiple alloying elements totaling less than 3% have recently been developed for use in the tempered martensitic condition with yield strengths approximating 100,000 psi. They are characterized by ready formability and weldability, and by high notch-toughness at any ambient temperature. Outstanding toughness has been reported in one of these steels tested as a restrained weldment at low temperature. Full-scale tests of pressure vessels made of another of

(Continued on p. 154)

Vacuum Melted Metal– An Interim Report

*By FRANK T. CHESNUT**

Vacuum melting can give cleaner metal and can control elements like aluminum and titanium added for precipitation hardening. The extra cost is justified for gas turbine blades and specialty applications, but as yet there is little consumption of vacuum melted alloy steels for conventional purposes. (C 25, D 8)

At the very outset an attempt was made to determine the present industrial uses of parts made from vacuum melted metal, and it was immediately apparent that these were not as numerous as the rash of recent notices in the technical and business press would indicate. Much experimentation was under way, but the consensus seemed to be that actual requirements of most parts could still be met by careful design and fabrication of alloys melted by more conventional methods, even though these same metallurgists did not argue that vacuum melted metals exhibited better physical properties when evaluated by the standard laboratory tests than the same nominal analysis melted under slag in open air. Economics rears its ugly head.

It was learned, as was expected, that vacuum metal was in use for making watch springs, X-ray and vacuum tube parts, magnetic alloys, metals for the atomic and jet engine programs, the production of titanium and molybdenum ingots and castings, the purification of germanium and silicon for transistors, the melting of metals for vaporization coatings, the simple outgassing of bronzes and aluminum alloys (and in Europe even large tonnage lots of steel melted in conventional ways) and finally for the sintering and hot pressing of carbides.

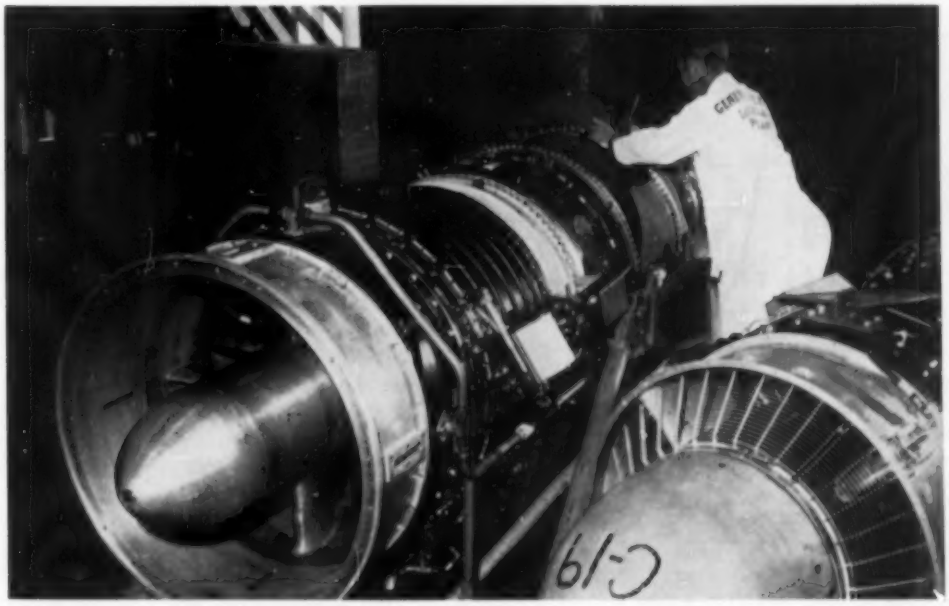
However, vacuum melted metals are apparently not now in production for ball bearings, valve springs, gas engines, power plants, chemical vessels, tools, stainless steel rolls whose surfaces must be free from flaws, molding dies, and corrosion resisting assemblies. Typical were comments from a large automobile maker that his company "does not use vacuum melted metals at the present time" but that research work is in progress; or from another prominent manufacturer that: "We are in the process of considerable testing of vacuum melted steel in ball bearings, but, unfortunately, do not have any material which we could release at the present time. We are not using vacuum furnaces."

Reports by Users

A prominent maker of aircraft engines reported, "There have, of course, been a lot of rumors and opinions regarding the virtues of metals which have been melted and cast under high vacuum.† It is my opinion that both sides of the argument require a good deal of consideration, but I do not think that we are in a position to make definite conclusions. Our greatest experience has been with turbine blade material, and it has been demonstrated beyond question that Waspaloy blades forged from rather small ingots, vacuum melted and cast, have higher rupture life, are more uniform and perform better in engines

*Electrical Engineer, Ajax Electrothermic Corp., Trenton, N. J. This is a portion of a paper read by Mr. Chesnut at the National Metal Congress meeting on Oct. 18, 1955, sponsored by the Industrial Heating Equipment Assoc. Matter in brackets has been inserted by the Editor – principally derived from the ASM Conference on Vacuum Melted Metals held the previous day.

†For the most part, "vacuum melted" metal means melting in crucibles wherein heat is supplied by induced electric currents. Arc melting into a cold crucible, the ordinary process for titanium, which has its own good and bad points, is not implied.



J-47 Turbojet Engine. (Courtesy General Electric Co.)

than any previously prepared by conventional melting, and all of our Waspaloy turbine blades are so made. Metals with titanium as an alloying element can be melted under high vacuum and be freer from contamination than if melted by conventional practice, but I am not at all sure that *pure* metals cannot be melted under argon or helium and be just as good.

"We are also evaluating vacuum melted steels for antifriction bearings. There have been some premature failures. It is my opinion that the low-alloy steels can be melted in air or special atmosphere and be just as clean as those melted under vacuum, and that steel companies will make every effort to do so.

"Some of the big problems have to do with ingot practice — just as with air melted materials. Hence, the improvements associated with small vacuum melts are not so clear-cut when making large ingots. In short, the segregation problem is not eliminated.

"I believe the most important use of vacuum melting today is in the titanium industry where most producers are melting with consumable electrodes in a vacuum. This is the only way of assuring low hydrogen in the product."

A maker of automotive and aircraft parts wrote, "Melting any given alloy in a vacuum does not assure a miraculous increase in physical properties. For certain alloys and certain properties improvement is possible, but only when proper techniques are used. We have a limited amount of stress-rupture tests on high-temperature alloys, melted in vacuum, which show a large scatter. Since the analyses are comparable, the differences can be attributed to differences in the melting procedures. I doubt if this point is generally recognized."

A chemical consultant sees promise in vacuum melted metals for pressure vessels, rolls and dies for the manufacture of plastics and the like "if laboratory data can be substantiated in actual large-scale production".

Current Problems

These quotations seem to agree that vacuum melted metals *can* have superior qualities but commercial use depends upon the ability of the steelmaker to work out melting techniques for each alloy. Costs also cannot be neglected. Even then, substantial use may have to wait until the user perfects his product to the point where vacuum melted metals are necessary and his prices can be adjusted to include the extra cost of his raw material. This day may not be too far off; one high-temperature alloy used in jet engines has had its design specifications revised upward four times in the past year, due almost entirely to knowledge gained by vacuum melting and the processing of the superior metal.

Producers have been working under a handicap, especially of late, because the demand for

Fig. 1 – Stress-Rupture Tests (Wrought Round Bars) of Waspaloy at 32,500 Psi. and 1500° F., Showing Variation Depending Upon Furnace Practice

refined metal has been limited in volume, and it has been necessary either to study only one or two alloys most in demand, or to go into extensive research on the techniques most desirable for all the interesting alloys. A well-equipped laboratory and a sizable amount of money are necessary before any return can be expected. As one producer put it, "Only after we have made ten carefully documented melts of a given alloy can we accept orders with the expectation of meeting specifications."

Another problem is competition. Suppose that the Government needs a large quantity of vacuum melted metals for the jet engine program and is willing to subsidize one or more producers, either existing or prospective. Acceptance specifications must be sufficiently high to gain the desired metal, but not so high as to discourage industrialists. Perhaps the specified alloy can be made by careful air or inert-atmosphere melting, or perhaps by vacuum induction or even by vacuum arc. The firm which originally installs vacuum induction melting equipment may find itself crowded out, as production grows, by others using the vacuum arc melting process – or vice versa. There is no assurance, either, that specifications will not change as demand and use grow, or that other alloys will not be found to meet the requirements. Although most of the high-temperature alloys that are now melted in vacuum use an induction coil as heating element, this may not always be true. It is entirely possible that a closely tailored analysis made in an ordinary induction furnace may be cast into consumable electrodes and then degasified by remelting in an automatic vacuum arc furnace. The final alloy might then have all the advantages of metal melted in a cold crucible, and still retain the homogeneity and close analysis given by initial melting in an induction furnace.

The present writer cannot draw any definite comparison between vacuum induction melted metals and vacuum arc melted metals. The two processes are not now competitive, since vacuum arc melting is limited to the titanium, molybdenum and similar reactive metals and their alloys, for which suitable refractories have not yet been found. The more complex alloys which can be retained in commercial refractories are generally melted in the vacuum induction furnace; these include the high-temperature analyses for the jet engine program, and considerable information is available from their producers, which number possibly 30 or 40, either active or prospective. They consequently offer the best basis for discussing the production methods and the physical qualities of the metals.

Jet Engine Blades

Waspaloy – Utica Drop Forge & Tool Corp. has melted 500,000 lb. of high-temperature alloys in vacuum and produced forgings therefrom in the last 30 months. The major production is Waspaloy (Table I), although M-252, Nimonic 90 and the firm's new alloy, Udimet 500, have been made commercially. Most of the output has been for the jet engine program, but some has gone elsewhere in pilot lots for further study. Utica operates two 100-kw., 300-lb. furnaces made by Ajax and two 300-kw., 1000-lb. furnaces made by Tocco. The vacuum equipment for the Utica furnaces was made by Stokes.

[Experience indicates that the process does not automatically insure a superior product. The mechanism must be in perfect condition, the crucibles prepared with meticulous care, the furnace crew trained to laboratory precision and in absolute discipline. Furnace practice – that is, detailed procedure during melting – is a large factor in the success. After such conditions have been achieved, Utica finds it can make as good metal now in 1000-lb. heats as formerly in 300 – and easier. . . . The furnaces absorb much circulating scrap from forge and machine shop. Satisfactory Waspaloy heats have been made with 70% scrap. There is especially good control of the reactive metals titanium and aluminum. For example in 200 consecutive heats, 23 analyzed 2.9% Ti, 140 analyzed the desired 3.0%, 28 analyzed 3.1%, and 9 were high or low. Aluminum in these heats was consistently between 1.15 and 1.35, and 20 were high or low. Furthermore, the resulting metal is notably free from aluminum

and titanium oxides, so all of these metals are useful in the precipitation hardening action . . . As to gases: Hydrogen is almost entirely eliminated; nitrogen is reduced somewhat, but oxygen as oxide in the original metal remains, even though vacuum at the end is 3 to 5 μ.]

Table I – Nominal Analyses of High-Temperature Alloys

Element	Waspaloy	M-252	Nimonic 90	Udimet 500	1570	R-235
Carbon	< 0.10	0.15	< 0.10	0.15	0.20	0.15
Manganese	< 1.00	—	< 1.0	< 0.75	—	—
Sulphur	< 0.030	—	—	0.015	—	—
Silicon	< 0.75	—	< 1.5	0.75	—	—
Chromium	20.0	19.0	20.0	17.5	20.0	15.0
Cobalt	13.5	10.0	18.0	16.5	38.0	—
Molybdenum	3.5	10.0	—	4.0	7.0*	5.5
Titanium	3.0	2.5	2.2	3.0	4.0	2.5
Aluminum	1.25	1.0	1.2	3.0	—	2.0
Iron	< 2.0	2.0	< 5.0	< 4.0	2.0	8.0
Nickel	Bal.†	55.0	Bal.	Bal.	28.0	Bal.

*Tungsten. †Copper less than 0.20%.

The staff at Utica stresses the fact that the physical properties (laboratory tests) of vacuum melted alloys may vary considerably depending upon the melting technique, or even vary between ingots poured successively from the same melt. By finding an optimum analysis and technique and painstakingly sticking to it, superior metal can be made. The curves of Fig. 1 bear this out.

[Waspaloy is also made by vacuum arc melting by Allegheny Ludlum Steel Corp. and Universal-Cyclops Steel Corp. Figure 2 compares 100-hr. stress-rupture strengths of the two varieties as made at present. Stress-rupture specification of 23 hr. at 32,500 psi. and 1500° F. was rather hard to meet at the beginning, but the first serious trouble was with the blades in engine tests, wherein brittle-type failures occurred in coarse-grained areas of blades operating at about 1350° F. This was cured by revising the forging process, enforcing a grain size specification, and instituting a very long heat treatment: solution heat treatment, 4 hr. at 1975° F.; stabilization, 24 hr. at 1550° F.; prior-to-precipitation heating, 16 hr. at 1400° F.; final grind and polish; stress relieve 16 hr. at 1500° F. . . . These blades operated so well that thrust on the engine was increased to 7250 lb., with corresponding increase in airfoil temperature, whereupon some blades failed by incipient stress-rupture cracking in the zone operating at 1600° F. Some of these brittle blades were then remelted in vacuo, and new blades forged from 6-lb. ingots. There was no discernible change in gas content or microstructure (although manganese was lowered – and, much more important, titanium can be increased to 3.0%) yet stress-rupture life was increased 50% and rupture ductility 100%. . . . Some 43,000 blades have been made for Pratt & Whitney Aircraft from vacuum melted ingots, and they have been extensively tested in comparison with blades from metal induction melted in air. Vacuum melting, as shown in Fig. 2, gives higher stress-rupture tests and results fall within a narrower scatter band. The 1350 and the 1600° F. "embrittlement" has been eliminated. Stress-rupture elongation, formerly 5%, is now 15% – a valuable cushion against sudden fracture. . . . The crux of the matter is engine testing. In this respect, blades from vacuum melted metals have had considerable success at high levels of performance.]

M-252 and 1570 – Carboloy Dept. of General Electric Co. has released some information on two of its high-temperature alloys, M-252 and 1570, vacuum melted, whose nominal composition is shown in Table I:

	M-252	1570
Stress-to-rupture at 100 hr. at 1500° F.	34,000 psi.	33,000
Stress-to-rupture at 1000 hr. at 1500° F.	18,000 psi.	24,000
Fatigue strength at 10^8 cycles	45,000 psi.*	48,000
Tensile strength at 1500° F.	91,000 psi.	82,000
Elongation	16%	14%

*40,500 when air melted.

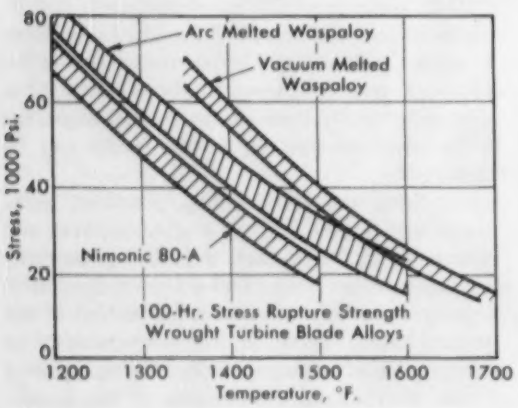
A feature stressed by Carboloy is this: Of a 1000-lb. ingot of M-252, air melted, only 550 lb. can be forged, whereas 700 lb. can be forged from a vacuum melted ingot. Whereas only 300 of the 450 lb .of generated scrap can be re-absorbed in subsequent melts from the air melted ingot, the full amount of vacuum melted scrap can be recharged.

[In fixing the correct shop practices, many ingots are forged into jet engine buckets and completely finished, each item being carefully inspected at each stage. Defects are judged as to severity on an arbitrary scale. Air melted M-252 buckets rated 78/166 in frequency/severity of defects, while vacuum melted buckets rated 33/66. Microscopic examination of the former

showed many inclusions of titanium carbo-nitride associated with upsetting cracks and surface flaws in the finished forging. The latter could be ground out, but vacuum melting reduced greatly this necessity. Room-temperature ductility in tensile tests is also greatly improved, values for elongation being 10% air melted and 15% vacuum melted, and reduction of area being 11% air melted and 16% vacuum melted. Finally, the scatter band of test results is narrower and acceptance requirements can be more rigid.]

[**R-235** is made by Haynes Stellite Co. in a 650-lb. furnace producing 450 to 500-lb. heats on a 3½-hr. melting cycle. Many heats made of all virgin metal have been compared with those made with 50% scrap and with all-scrap heats, and no significant differences found. At meltdown the vacuum is about 130 microns, and thin patches of slag float on the surface. This is principally titanium nitride which dissociates within 30 min. as the pressure is reduced to 7 microns; some oxide is also reduced by carbon in the metal, the nitrogen and CO being pumped off. Possibly a little magnesia in the crucible is also reduced by carbon, the magnesium also vaporizing. In fact, after several dozen runs the interior of the furnace enclosure was cleaned and the scrapings examined spectroscopically. Some strange metals like gallium appeared, undoubtedly derived from the melting stock where they existed in amounts too small for analytical detection, but possibly large enough to influence physical properties and utility of critical parts. . . . Air melted ingots show perhaps 30 inclusions on a slice at mid-section; in vacuum melted ingots the number is three or four and they are very

Fig. 2 – Scatter Bands of Stress-Rupture Tests on Two Wrought Turbine Blade Alloys and Two Methods of Melting



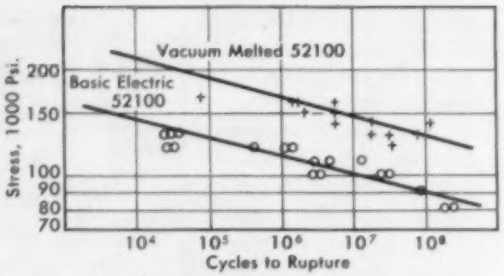


Fig. 3 – Log-Log Plot Showing Cycles to Rupture in Standard Fatigue Test of 52100, Basic Electric Versus Vacuum Melted

much smaller. This is one factor in improving hot workability to where sheet can be rolled without ruinous edge cracking. (It is a general observation that vacuum melting improves hot working characteristics.) Such sheet also, being practically free from harmful inclusions, gives as good stress-rupture tests as bar samples.]

Magnetic Alloys

Work at Naval Ordnance Laboratory at White Oak, Md., on high aluminum-iron alloys is worthy of mention. Short of nickel during the War, the Japanese made satisfactory magnetic materials of 12 to 14% aluminum ("Alfer") for magnetostrictive devices and of 14 to 16% aluminum ("Alperm") for magnetic laminations. They were induction-furnace melted and the total yield was anywhere from 30 to 50%, depending largely on chance. The alloys were extremely brittle and most of the loss occurred during hot and cold rolling operations.

The Naval Ordnance Laboratory, working on alloys of 16% aluminum, balance iron ("Alfenol"), and 16% aluminum, 3% molybdenum and balance iron ("Thermenol"), found that hot and cold shortness could be largely overcome by melting in low vacuum and controlled atmosphere. An Ajax vacuum furnace was used.

The iron, aluminum and molybdenum are of high purity to start. The iron is charged into the furnace and pressure is reduced to around 0.2 cm. As the iron melts, gas is given off and the pressure rises to 0.5 or 1.0 cm. The iron is then decarburized for 30 min. under wet hydrogen, and deoxidized for another half hour with dry hydrogen. The furnace is then purged with pure, dry helium and pumped down to about 2.5 mm. pressure to remove dissolved hydrogen. The system is then refilled with helium, aluminum is added, temperature adjusted to 1650° C. (3000° F.) and cast.

Alfenol is a substitute for high-permeability magnetic materials containing large amounts of strategic nickel or cobalt. Thermenol, substantially the same composition plus 3% Mo, has exceptional high-temperature qualities and looks very good for such uses as resistance heating elements, for hot spots in aircraft replacing certain grades of stainless steel, jet engine parts, and magnetic tape.

Antifriction Bearings

Vacuum Metals Corp. of Syracuse (jointly owned by Crucible Steel Co. of America and National Research Corp.) operates 200-kw., 650-lb. and 300-lb. vacuum induction furnaces. A 2500-lb. furnace is soon to go into operation. Experience indicates that it is easier, in fact, to control the 650-lb. furnace than the small one. For example, chromium in 52100 is held between 1.43 and 1.55%. The largest tonnage is in steels used for heavily loaded bearings and for instrument bearings. Most production is of the 52100 steels (1% C, 1.50% Cr); some 51100 (1% C, 1% Cr) and high speed toolsteels are made. When vacuum melted steels are made into heavily loaded bearings and tested for endurance, the scatter of results, particularly on the lower side of the band, is lessened, thus greatly decreasing the chance of premature failure. Carboloy also reports that bearings made of 52100, vacuum melted, show a four-fold increase in service life.

In antifriction bearings for instruments the surface finish is extremely important. Inspection rejections for surface imperfections caused by inclusions are virtually eliminated.

[It has long been known that when 52100 steel containing many inclusions is made into ball or roller bearings, it will have low life under test. The same steel with average inclusions will have the expected life, and exceptionally clean steel will give long-lived bearings under test. For this reason the number and size of inclusions have been specified. Other than to acknowledge that vacuum melted steel is consistently clean, and has superior endurance in standard laboratory tests (Fig. 3) manufacturers of bearings are hesitant to ascribe unusual virtues to the metal. Present premiums for vacuum melted 52100 in bars or rods are at least 50% over conventionally made steel, even on large orders, and a large premium is bound to remain. This will be a ruling factor in the highly competitive field of bearings for all types of machinery except where long performance at maximum load outweighs everything else.]

Economics

Universal-Cyclops Steel Corp. points out that the economics of vacuum melting will not be clear for some time. (This firm operates one specially built 350-kw., 1000-lb. semicontinuous furnace, and one 100-kw., 50-lb. furnace of more conventional design. Its experience, through key personnel, dates back to 1946.) Insufficient metals of each class have been melted for a complete economic picture. This company believes some alloys can eventually be melted in vacuum at prices comparable to conventional melting, balancing higher furnace costs against a better yield of good metal and less slagging of valuable addition elements. However, Universal-Cyclops suggests that vacuum melted alloys might very generally be priced at $1.00 per lb. over conventionally melted alloy, with a minimum price of $2.50 per lb. Others think this price too low and suggest an extra of about $1.50. But this is just a very general figure. Quotations will vary widely depending upon the alloy, the background of knowledge in making it, and the quantity involved.

[An estimate of future expectancy for tonnage production can be made from a curve parallel to one showing growth of electric furnace steel. Induction vacuum melting started in 1945; five years later 30 tons were so made; in 1955 production will be about 700 tons. Planned capacity as of 1957 will be 7000 tons. Extrapolating from these meager data gives a Yankee guess of 70,000 tons of vacuum melted steel and high alloy, and a hopeful prediction that it should be 1% of the total steel production by 1970.]

Conclusion

This then is the status of vacuum melting. For some alloys it is essential and required, and present use is expanding. Alloys of vastly superior high-temperature and corrosion resisting qualities have been made, and their physical characteristics have been proven and documented. They are being used widely in certain restricted and subsidized applications. Production capacity at the moment exceeds demand, and peacetime industry has not yet contracted for sizable tonnages. Perhaps metallurgy is ahead of industry and must pause while industry catches up. Perhaps, as the jet age and atomics spill over into private industry, vacuum metals will be in high demand. Perhaps, with improved processing and lower cost, vacuum melted metals will usher in the gas turbine for automobiles.

Welding Engineers Consider Many Topics of the Times

*Reported by DAN WHITE**

A gamut of questions regarding efficient welding was discussed, ranging from oxy-acetylene welding of aluminum to resistance welding of titanium and from manufacture of high-pressure equipment to automation of cylinder manufacture. (K general)

A THREE-RING CIRCUS is a weak simile for the National Metal Congress and Exposition. Even though this correspondent was asked to report the doings of the American Welding Society, there were usually about five things for him to choose from – one of three technical sessions, an inspection trip, or the exhibits at the Exposition Hall, to say nothing of district meetings, luncheons and ten committee meetings. One could go from 9:30 in the morning until 10:30 at night and still miss the most of it! As always, the cloakroom gossip and off-the-cuff discussions with friends solved many a knotty problem. Furthermore, the 62 scheduled papers were largely devoted to welding processes and applications.

Automation is a subject which must appear in any well-regulated discussion. Automation of metal manufacture will undoubtedly lean heavily on the various fusion welding processes. The designer of such a system must select the process best suited, and the machinery for its correct application to a given product. The various arc welding processes can be analyzed in respect to their salient features and their respective limitations, particularly as to physical properties of the weld, economics, and the degree to which each process itself may be fitted into the full automation of a production line. Automation welding, whether it be inert-gas metal-arc, inert-gas tungsten-arc, or submerged-arc, should be admirably suited. One example described at this meeting is a completely automatic machine with an arc that jumps from one cylinder to another as the parts are indexed. Each piece is rotated during welding.

Shielding of hot metal as it is transferred from electrode or rod into the joint is no new subject,

*Engineering Consultant, Lakewood, Ohio.

but the amount of attention still being given to this problem by students of welding is evidence that it has not yet been satisfactorily solved for all metals and needs. Most recently carbon dioxide has been proposed as a shielding gas. The idea is now going through a period of development and standardization. Papers were presented concerning moisture in the gas, electrode characteristics for rimmed and semikilled steel, and new equipment designed especially for this process.

Progress in what might be thought of as the matured art of submerged-arc welding was shown by comparing the numerous applications and techniques. New agglomerated fluxes have been devised containing various alloys. By mixing these in the proper combination, a flux can be created to produce alloy deposits with wide ranges of chemical and physical properties. Their advantages are the ability to meet any job requirement and availability economically and quickly in either large or small quantities.

Welding Rods — Very active interest was shown in new welding rods. A special rod to weld "Carilloy-T-1" steel, described in "Critical Points" in *Metal Progress* for September 1954, with improved low-temperature impact resistance in the stress-relieved condition produced a lively discussion about the evaluation of this type of data.

American development of low-hydrogen electrodes containing large quantities of iron powder in the coatings is about one year behind the use of coatings containing rutile and iron oxide. Some brands are now on the market. Perhaps the greatest single advantage of this type over conventional electrodes is their ability to lay down metal into the joint at increasing rates. The coatings cost more, but not as much as you save in welder's labor.

Projection Welding — An extensive program of developing schedules for welding projection "hardware" to low-carbon steel has recently been completed. Welding of typical items such as pilot nuts, brackets, angles, bolts, spacers, pins, and T-nuts was fully covered in the test. Sheet and plate thicknesses to which the items are welded range from 0.032 to 0.250 in. inclusive.

Brittle Failures

In the sessions on weldability and research special attention was given to the cause and prevention of cracks and tears.

Failures of oil storage tanks led to efforts to simulate such failures in the laboratory in tests of plates of full thickness. Preliminary studies with plates up to 6 ft. wide indicated that below a certain temperature the stress required to sustain a moving crack, even in a very large structure subjected to a small stress transient at a defect, is of the order of 10,000 psi. A procedure was devised to determine the brittle temperature at 18,000 psi., and comparisons were made of a number of plates from different heats of steel in several grades. It was established that this brittle temperature agreed with the temperature at which the V-notch Charpy impact test yields 15 ft-lb. in ordinary plate steels, and 30 ft-lb. in low-carbon, high-manganese plate steels. It would thus appear that the Charpy test may be used to evaluate the "transition" temperature, above which the plate is "tough" and below which the plate is "brittle". Steelmaking practice has some effect on this temperature. For a given practice the most important variable is the carbon content; the effects of other elements including manganese are apparently quite minor at the same strength level.

Fatigue tests on welded joints indicate that all of the low-alloy steels are extremely sensitive to the presence of notches under alternating loads. No welded joint under test was proportionately stronger in fatigue than ordinary A-7 steels* in proportion to their increased yield strength over the specified 33,000 psi. for plain carbon structural steel.

It has become customary to recommend the preheating of higher carbon and alloy steels, or post-heating, or stress-relief of weldments. Preheating serves mainly to mitigate stresses originating from the thermal shock of the arc. The secondary function is to minimize notch sensitivity or to increase ductility of the metal joined, on the assumption that it might not be in the optimum annealed condition. A high cooling rate from the welding operation leads to the formation of martensite and a highly stressed weldment. The rate of cooling may vary within rather wide limits. Low-carbon steel may have a martensitic structure at spot welds, but this is much less likely to happen to large sections where the dwell of the current is longer, or where multi-beads are required. If the whole metal at and alongside the joint is preheated above the Ms temperature, where martensite starts to form, then the highly heated zone at the weld will cool rapidly to the preheat temperature but no martensite will form. On subsequent cooling martensite formation will be retarded. This is not as good practice as it may appear, because the austenite formed at the hot

*American Society for Testing Materials specification A-7 for steel for bridges and buildings.

weld in alloy steel may be partially retained on cooling, then transform to martensite on subsequent stress-relieving.

The welding electrodes commonly used for mild steel have greater notch toughness than the structural mild steels. They have a transition temperature at around 60° F. and should not be used for severe service at frigid temperatures. Crack-starter tests have demonstrated the feasibility of using highly notch-tough welds (ferritic and austenitic) to stop the propagation of cracks in such structural mild steels. Simple bead-on-plate welds of notch-tough weld metals are effective in stopping cracks even under dynamic loads. An ordinary structural plate will fragment in crack-starter tests at zero to 40° F., but in similar tests plates having a ring-like overlay of notch-tough weld metal remained intact. The fractures run from the crack-starter to the overlay and are stopped there.

Various Metals

Cast Iron – Weldability of both gray and nodular cast iron is evaluated by a new type of grooved test block. This is used to compare welding techniques, processes, and filler materials. The data are most useful to those also who repair iron castings, although they can also be applied to fabrication welding of castings.

This evaluation of weld processes produced some startling results. Some comfortable assumptions about the welding of cast iron have been abandoned, and welders are finding that certain problems believed to have been solved have merely been ignored.

Stainless Steel – In the welding of stainless steel, some progress has been made in understanding and eliminating cracks near and in the welds. This whole problem is complicated by one unique requirement, namely, that corrosion resistance of the joint or the base metal must not be harmed by the fabrication method. Simple welding tests evaluated cracking propensities of weld and base metal for various heats and forgings of Type 347 (columbium-stabilized 18-8) and Type 304 (plain 18-8) stainless steels. Seemingly hot cracks develop in the base metal by the liquation of fusible grain-boundary segregates. They impose high strain concentrations upon the solidifying weld metal and promote the extension of these cracks into the base metal.

There is a considerable difference of opinion about the correct nature of the weld metal – should it be fully austenitic or should it have a considerable fraction of alpha?

Presence of primary ferrite in the weld metal is supposed to reduce the notch sensitivity, or the extension of cracks, and one speaker described a series of tests on welds involving different base metals and electrodes with increasing amounts of ferrite. The results indicated that the more highly austenitic base materials require electrodes with higher ferrite to supress the extension of cracks from weld notches.

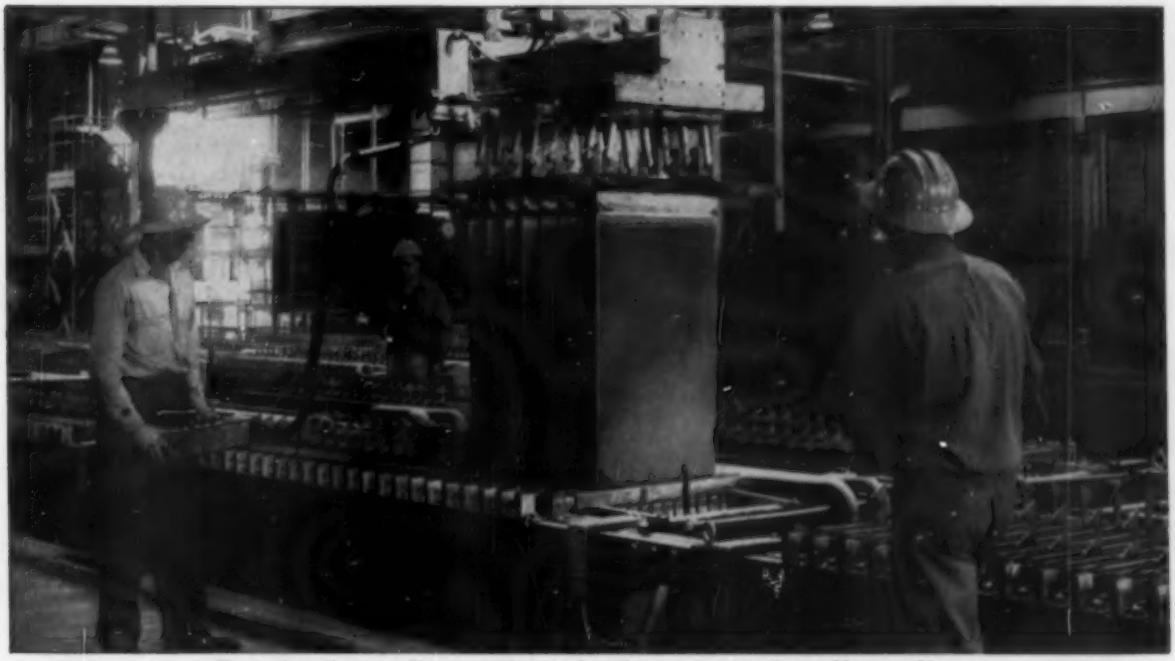
Aluminum – The competition between various welding processes for aluminum alloys has resulted in some unexpected observations. One aircraft manufacturer reports that oxy-acetylene welding of aluminum alloys seems to be generally superior to oxy-hydrogen welding, in both quality and economy. There are also indications that it is often superior to inert-gas welding at least for the light gages used in aircraft.

Another aircraft man proceeded to show that there is a good opportunity to improve inert-gas welding, since the composition of the shielding gas used for consumable-electrode and tungsten-arc welding has a pronounced effect on ease of welding, porosity in the welds, susceptibility to hot-short cracking during welding and costs. In his opinion the best gas mixture is one containing about 65% helium and 35% argon. Fast wetting of the base metal by the filler metal, a feature that is characteristic of welds made in helium, results from this mixture, together with the good arc stability and freedom from spatter that is characteristic of welds made in argon.

There has long been a need for a method of welding aluminum to copper – particularly for busbar applications. Such joints made by the inert-gas metal-arc process are satisfactory when the surfaces to be welded are properly prepared.

Molybdenum – The specific deleterious effects of oxygen in the welding atmosphere have been established with respect to hot weld bead cracking, and the brittle-to-ductile transition temperature of the joints in molybdenum. Changes in the brittle failure temperature and the stresses at which failures occur are related to the oxygen content of the inert-gas welding atmosphere and therefore of the weld metal. Rules were presented for controlling the welding atmosphere for welds having maximum grain size for usable ductility.

Titanium – Advances in electronic controls for resistance welding machines have enabled welding engineers to develop a welding schedule for titanium using critical preheat, weld, and post-heat times and currents. As a result an extremely ductile spot weld can be made in commercially pure titanium.



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Personal Mention

Robert M. Brick

ROBERT M. BRICK, former director of the school of metallurgical engineering at the University of Pennsylvania, has been appointed director of the department of metallurgy in the central research and engineering division of Continental Can Co., New York. Dr. Brick is a consultant to the Frankford Arsenal of the U. S. Army and to the U. S. Atomic Energy Commission's installations, and a former consultant to the Oak Ridge National Laboratory, Oak Ridge, Tenn.

Graduating at Lehigh University as a metallurgical engineer in 1929, his industrial experience included employment by the Aluminum Co. of America, Bethlehem Steel, and consulting work for numerous metal producers, fabricators and users. His academic career has included membership on the faculty of Yale University, from which he obtained his Ph.D. degree in 1933. He is the author of numerous papers in the field of physical metallurgy, as well as the author of the textbook "Structure and Properties of Alloys" which was published in 1942 and followed by a second edition in 1949. Dr. Brick is listed in "Who's Who in Engineering", and is a member of the Ship Steel Committee of the National Research Council, the American Institute of Mining and Metallurgical Engineers, and the British Institute of Metals.

Darwyn I. Brown

DARWYN I. BROWN has joined the staff of Washington Steel Corp., Washington, Pa., as assistant to the president. Born in Youngstown, Ohio, Mr. Brown started his industrial career with Youngstown Sheet & Tube Co. in 1934. He worked for Carnegie-Illinois Steel Co. in Youngstown and the U. S. Steel Research Laboratory in Kearny, N. J., before being named metallurgical contact representative for the U. S. Steel Alloy Bureau in Pittsburgh. In 1946, Mr. Brown became Chicago editor of *Iron Age*. Four years later he moved to New York as metallurgical editor, and later was technical editor. In 1953, he joined Mullins Mfg. Co., Salem, Ohio, as manager of market development, and remained in that position until his present appointment. Mr. Brown studied metallurgical engineering at Youngstown College and Carnegie Institute of Technology, and during World War II served on the Ferrous Metallurgical Advisory Board. He is a member of the American Institute of Mining and Metallurgical Engineers as well as A.S.M.

Jack Collins, formerly metallurgical engineer with the technical service and development department of Electro Metallurgical Co., Niagara Falls, N. Y., has been transferred to the Pittsburgh sales office as a salesman.

Frank Kiper, formerly vice-president of the Misco Corp., Chicago, has been appointed president and general manager of Michigan-Standard Alloy Casting Co., Detroit, a division of Consolidated Foundries and Mfg. Corp.

Henry M. Heyn was recently elected a vice-president of Surface Combustion Corp., Toledo, Ohio, after having been sales manager of the heat treat division since 1930.

Clifford A. Hampel has joined Fansteel Metallurgical Corp., North Chicago, Ill., as manager of the chemical equipment division. His professional career includes research and development work with a number of the leading chemical industries and with Armour Research Foundation. He is the editor of Rare Metals Handbook and of the Encyclopedia of Chemical Reactions.

Henry Davis has been appointed director of sales and purchasing of American Iron and Supply Co., Minneapolis, Minn.

Richard C. Campbell has joined Metal & Thermit Corp., New York, as metallurgical sales engineer. He was previously connected with the Watson-Flagg Machine Co., Paterson, N.J., as sales and metallurgical engineer. A graduate of Newark College of Engineering in 1949, Mr. Campbell is now working on his M.A. degree in metallurgy at Stevens Institute of Technology.

Norman W. Calkins has been appointed assistant manager of toolsteel sales and assistant to the vice-president of Universal-Cyclops Steel Corp., making his headquarters at the Cyclops Division in Titusville, Pa. Mr. Calkins has been a member of the Carpenter Steel Co. sales organization for the past nine years.

Harry Schwartzbart has been promoted from research metallurgist to supervisor of welding research in the metals research department at Armour Research Foundation of Illinois Institute of Technology, Chicago. Before joining the Foundation in 1951, Mr. Schwartzbart served three years as a research metallurgist for the National Advisory Committee for Aeronautics, Cleveland.

G-E Type AK-1-50 Electrically Operated Air Circuit Breaker, 1600-amperes, 600 Volts, A-C. One pole shown. Made by General Electric Company, Low Voltage Switchgear Department, 6901 Elmwood Ave., Philadelphia, Pa.

Here is the General Electric Type AK-1-50 Electrically Operated Air Circuit Breaker, 1600-ampere frame size used to protect low-voltage systems. The picture shows one pole of the contact, and in order to photograph it, the housing and the arc-quencher parts were removed. Note the Revere Extruded Shapes, and Rectangular Rod. There are three shapes, and one size of bar, all in copper, because copper has the highest electrical conductivity of all commercial metals.

If these shapes had to be "hogged" out of bar, they would be expensive, due to the machining time, and the scrap generated. While copper scrap is readily salable at good prices, it is costly from the machining standpoint. Extruded shapes by Revere, preformed to the desired contours, usually reduce machining to a cutting-off operation, plus such minor details as drilling which cannot be done during extrusion. Shapes naturally cost more per pound than bar or rod, but the ultimate saving makes up for the difference and more, sometimes several times.

Are you doing much machining of copper? If so, look into Revere Extruded Shapes. They may save money, and speed up production as well. See the nearest Revere Sales Office.

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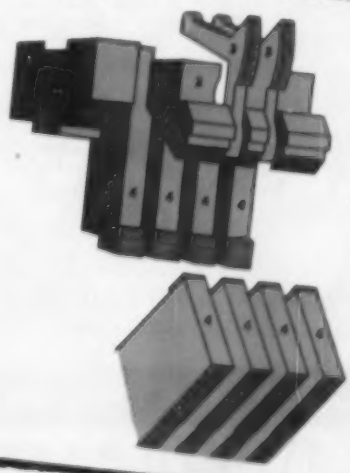
Mills: Baltimore, Md.; Chicago and Clinton, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Rome, N. Y. —Sales Offices in Principal Cities, Distributors Everywhere

Sketch showing details of contacts. Nos. 1, 2 and 3 are extruded and drawn copper shapes. No. 4 is rectangular copper bar. Cross hatching represents special arcing contacts brazed to the copper.



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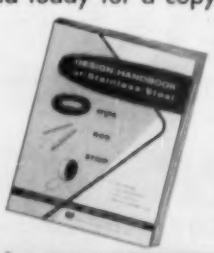
Does your Fine Wire application call for resistance to heat? . . . to corrosion? Does it require good fatigue properties . . . excellent weaving or other forming characteristics? There's a good chance you will find the material you need among the more than 20 grades of stainless steel we fabricate into high quality Fine Wire. No other family of metals has the combination of properties common to the stainless steels.

Learn more about the interesting properties and applications of our stainless steel Fine Wire, as well as our stainless Rod and Strip . . . send today for a copy of our new 40 page Stainless Steel Design Handbook.



ALLOY METAL WIRE DIVISION

HKP

H. K. PORTER COMPANY, INC.
Prospect Park, Pennsylvania

Personals . . .

John W. Buskie ⓜ, since August 1954 a consultant for Tennessee Products & Chemical Corp. and Tenn-Tex Alloy and Chemical Corp., divisions of Merritt-Chapman & Scott Corp., has been elected vice-president of Tenn-Tex Alloy and Chemical Corp. and will continue as a consultant for Tennessee Products and Chemical Corp. From 1949 to 1954, Mr. Buskie was general manager of metallurgy and development for Ohio Ferro Alloys Corp.

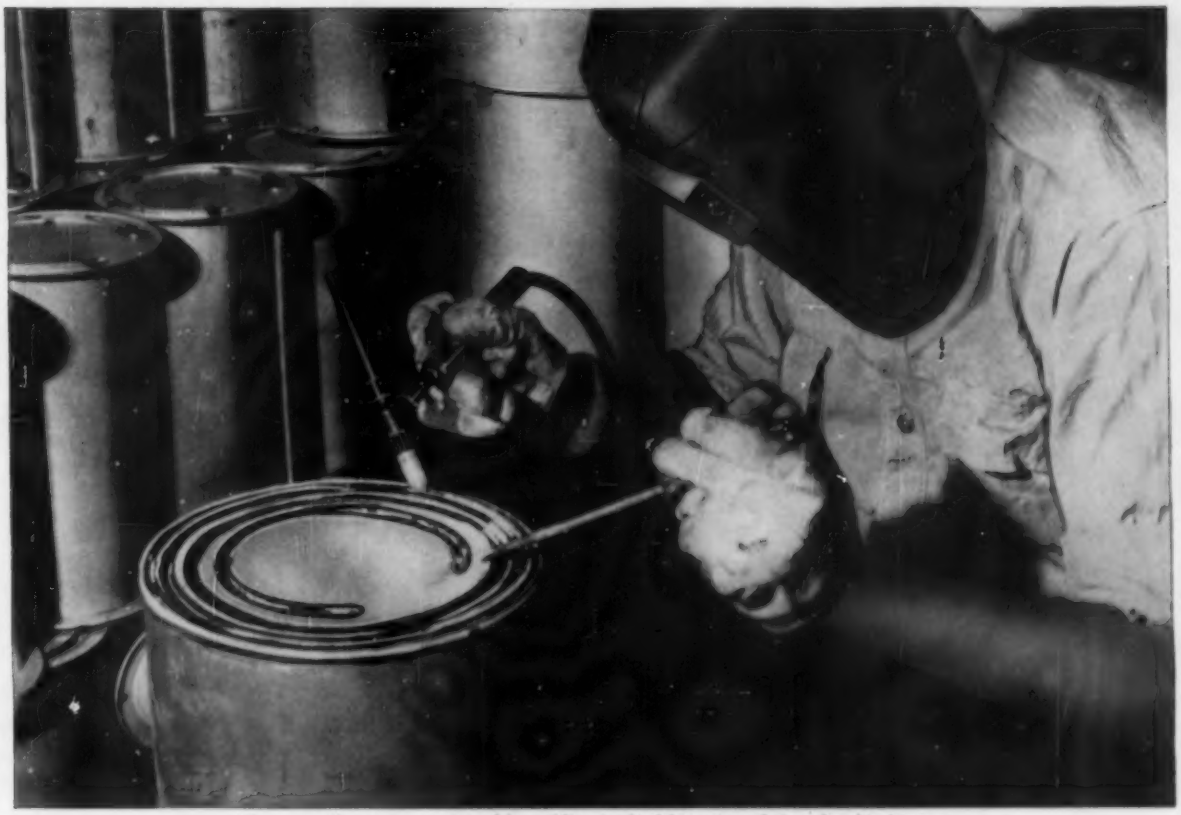
James H. Bechtold ⓜ, advisory metallurgist in the metallurgy department of the research laboratories of Westinghouse Electric Corp., Pittsburgh, has been named manager of that department. Mr. Bechtold graduated in 1949 with an M.S. degree in metallurgy from the University of Illinois, where he also served as instructor in metallurgy. He joined the Westinghouse research laboratories as a research engineer the same year, and early in 1955 was named advisory metallurgist to the department.

Norbert L. Kopchinski ⓜ, formerly welding engineer with Grumman Aircraft Corp., Bethpage, N.Y., has accepted a position as manufacturing engineer, nuclear research and development division, with the Glenn L. Martin Co., Baltimore.

Alan Swabey ⓜ has been elected as new president of the Patent Institute of Canada.

M. J. Weldon ⓜ, formerly metallurgist with the Henry G. Thompson and Son Co., New Haven, Conn., is now with the newly formed Northeastern Steel Corp., Bridgeport, Conn. Mr. Weldon is chairman of the ⓜ New Haven Chapter.

T. Coolidge Sherman ⓜ was recently appointed Washington, D.C., representative for Allegheny Ludlum Steel Corp. After graduating from Yale University in 1916, Mr. Sherman joined the Ludlum Steel Co. in Watervliet, N.Y., and when that company merged with Allegheny Steel Co. in 1938 he continued with the new organization. He has served in various executive sales positions, including manager of trade relations and assistant general manager of sales.



MULTIMET alloy wraps are joined by welding in the fabrication of aircraft cabin heaters.

MULTIMET Alloy Wraps Absorb the Heat from a 3500 deg. F Flame

MULTIMET alloy wraps are used to absorb the intense heat from burning aviation gasoline in aircraft cabin heaters. The spirally wrapped alloy sheet transfers the combustion heat to fresh ventilating air. Very thin sheet — only 0.025 in. thick—does an excellent job here despite the high metal temperatures and the oxidizing conditions.

Rigorous 1,000-hr. tests were conducted before MULTIMET alloy was selected for this job. It has now been the standard material for seven years. The excellent high-temperature properties of the alloy made it possible for designers to use thin sections, which insure a light, compact heater, with excellent heat-transfer efficiency.

MULTIMET alloy is one of many HAYNES high-temperature alloys for economical use over a wide range of operating conditions. It has given good service for engine manifolds, turbine blading, heat-treating equipment and many aircraft components. For a copy of a booklet describing HAYNES high-temperature alloys, and for prices and sizes of MULTIMET alloy, get in touch with the nearest Haynes Stellite Company office.

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HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

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Invaluable for tool room use and most production testing

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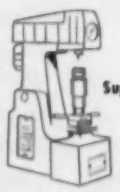

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Tukon Micro and Macro Hardness Testers

• WILSON "Rockwell" Hardness Testers were the first to combine in one high grade instrument the precision and sensitivity demanded in the metallurgical laboratory, the accuracy required in the tool room *plus* the ease of operation and durability for daily use on the production line.

Now the world's standard of accurate hardness tests since 1921, WILSON "Rockwell" Hardness Testers have developed to keep pace with the ever-expanding requirements of industry. Their testing scope and capacity has increased until their use in steel mills, non-ferrous mills and metal fabricating plants is universal.

A staff of WILSON hardness-testing experts is conveniently located to check your needs with you—recommend just the size and model best suited to the job. Why not call or write today?

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Personals . . .

John B. Adamec, Jr., research metallurgist of Sintercast Corp. of America, Yonkers, N.Y., has been appointed chief metallurgical engineer.

Bruce M. Lane and **Neal Griffing** were recent appointments to the staff of the metals research laboratories of Electro Metallurgical Co., a division of Union Carbide and Carbon Corp., Niagara Falls, N.Y. Mr. Lane was appointed technical assistant in the minerals and chemical engineering group. Mr. Griffing has been assigned to the metals research group of Electro Metallurgical as a technical assistant.

Albert W. Lange has been appointed sales representative in the New York City area for the industrial division of Henry Disston & Sons, Inc., Philadelphia. Mr. Lange was previously with Mid-Island Supply Co. of Long Island, New York.

Madan M. Nanda, formerly with the E. F. Houghton & Co., Philadelphia, recently joined Crucible Steel Co. of America, Harrison, N.J., as a metallurgist in the precision investment casting foundry.

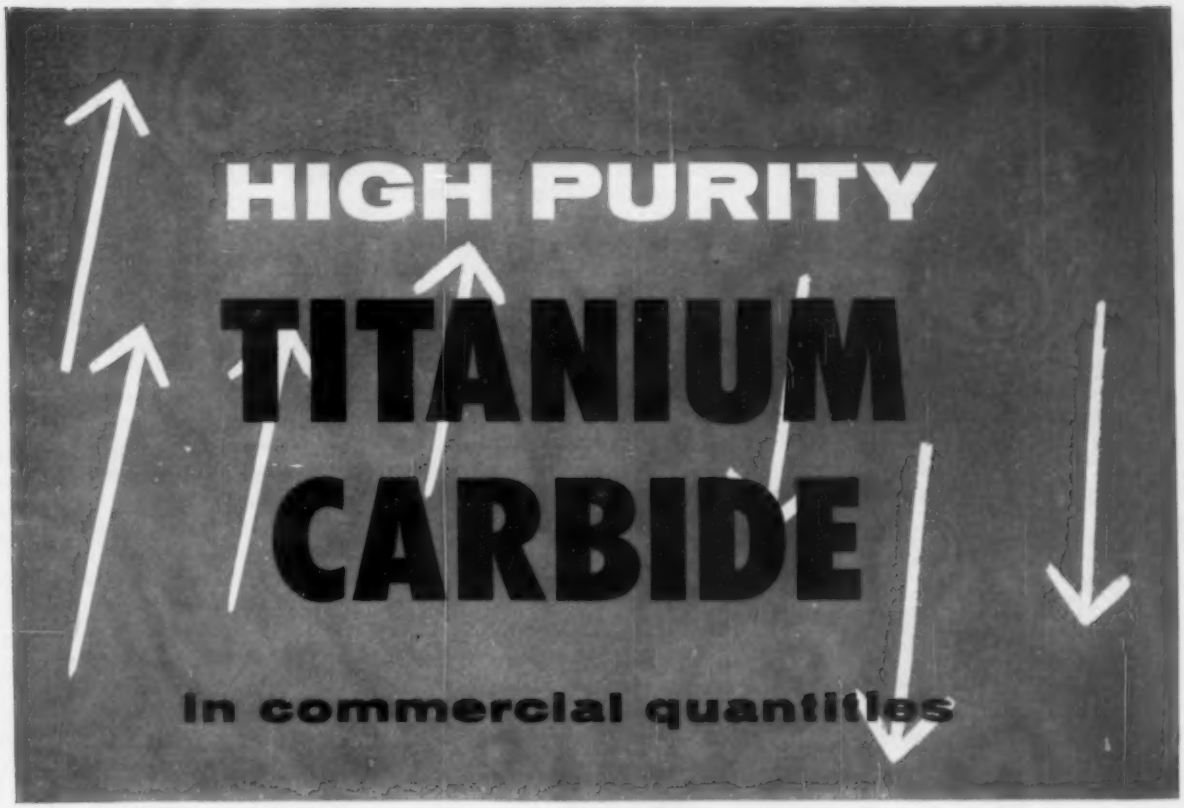
John A. Petroskas has been appointed chief metallurgist of Phoenix Iron & Steel Co., Phoenixville, Pa., subsidiary of Barium Steel Corp. Mr. Petroskas was formerly chief metallurist for the Midvale Co., and more recently superintendent of the forge and heat treatment departments of Fairmount Steel Corp.

Robert S. Mack has been appointed district representative for the eastern part of the United States for LaSalle Steel Co., Chicago.

V. R. Jaeger is the new district manager of the Roll-Bond division of Olin Mathieson Chemical Corp., with offices in White Plains, N. Y.

J. Gurland, formerly manager of basic research at Firth Sterling, Inc., Pittsburgh, has accepted an appointment as assistant professor in the division of metallurgy at Brown University.

William D. W. McMullen, a recent graduate of the University of Utah, is a graduate student at Lehigh University. Mr. McMullen is a recipient of a Gotshall Scholarship.



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PROPERTIES

Structure . . . :ubic	**Hardness . . . . . 9 Moh scale**
Mp . . . . . 5680°F	**Mesh Size . . . . 95 to 98%-325**

(also finer particle sizes 10 microns max. and 5 microns max.)

ANALYSIS of current commercial production of TAM* Titanium Carbide shows this high purity:

Combined Carbon . . 19.0% Min.	**Ti . . 79.0% Min.**
Free Carbon . . . . . 0.3% Max.	**Fe . . 0.2% Max.**

AS A DEVELOPER of metals, alloys, chemicals and compounds of both Titanium and Zirconium . . . TAM* is experienced and equipped to serve your needs for these products.

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NATIONAL LEAD COMPANY

Executive and Sales Offices: 111 Broadway, New York City
General Offices, Works and Research Laboratories: Niagara Falls, New York

Personals . . .

Robert E. Bockrath, for the past ten and a half years supervisor of magnesium sales in the Houston, Tex., office, has been transferred by Dow Chemical Co. to the Midland, Mich., office in the magnesium technical service.

E. Don Dilling, after 18 years' service with the U.S. Bureau of Mines, has joined the technical department staff of Titanium Metals Corp. of America, Henderson, Nev., as development engineer. For the past two and a half years Mr. Dilling has been in charge of the pilot plant at Albany, Ore., which is operated by the Bureau of Mines.

Alfred J. Brothers has been extended an educational leave of absence from Consolidated Vultee Aircraft Corp., San Diego, Calif., to attend the University of Michigan as a graduate student in the department of metallurgical engineering.

Ormond F. Whipple, after 21 years in various capacities in the automotive industry, has become president of Parks-Whipple, Inc., Fort Lauderdale, Fla., a concern manufacturing cultivators.

George W. Cunningham, a graduate of the University of Tennessee, has accepted a job at Battelle Memorial Institute, Columbus, Ohio, as a research metallurgist in the Reactor Metallurgy Div.

L. F. Mondolfo, acting department director, was recently advanced to director of the department of metallurgical engineering at the Illinois Institute of Technology. Dr. Mondolfo, who was educated at the University of Bologna and the Polytechnic Institute of Milan, Italy, was a research metallurgist for several U.S. companies before becoming a member of the staff of Illinois Tech in 1947.

Bani R. Banerjee, formerly assistant project engineer, was promoted to the supervisory position of group leader, X-ray and electron diffraction group, in the engineering research department, Standard Oil Co., Whiting, Ind. A native of Calcutta, India, Dr. Banerjee is a graduate in metallurgy of the University of Calcutta and received his M.S. and Ph.D. degrees from Yale University. He has taught at Illinois Institute of Technology and the University of Calcutta.

Robert N. Lynch has been appointed general sales manager of the Park Chemical Co., Detroit. In the sales department since 1940, Mr. Lynch was made industrial division sales manager in 1949. In the same company, **James L. Hagen** has been named manager of the special products division.

Branch M. McNeely, Jr. has joined the development and research division of the International Nickel Co., Inc., as a member of the Texas technical field section with headquarters in Houston, Tex. Following his graduation from Clemson Agricultural and Mechanical College in 1948 he joined the Houston Oil Field Material Co. In August 1953 he was appointed assistant chief engineer, and served in that capacity until joining International Nickel.

Kenneth H. Moyer, previously employed in the research laboratories of International Nickel Co., New York, is now a metallurgist for Grumman Aircraft Engineering Corp., Bethpage, L.I., N.Y.

Howard Friedman, who obtained the degree of B.S. in metallurgical engineering from the University of Illinois in June 1955, is now employed as research assistant on the fiber metallurgy program at Armour Research Foundation of Illinois Institute of Technology.

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General-Purpose Sawing

with

High Speed

Accuracy, Economy

Model 4B/M2/E2
Equipped with standard work track
(Optional Equipment).

Let us prove to you the many reasons why this MARVEL Hack Saw offers the cheapest, most accurate and fastest "cut-off" method available to you at a low initial cost.

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HIGH SPEED HACK SAW

Exclusive features

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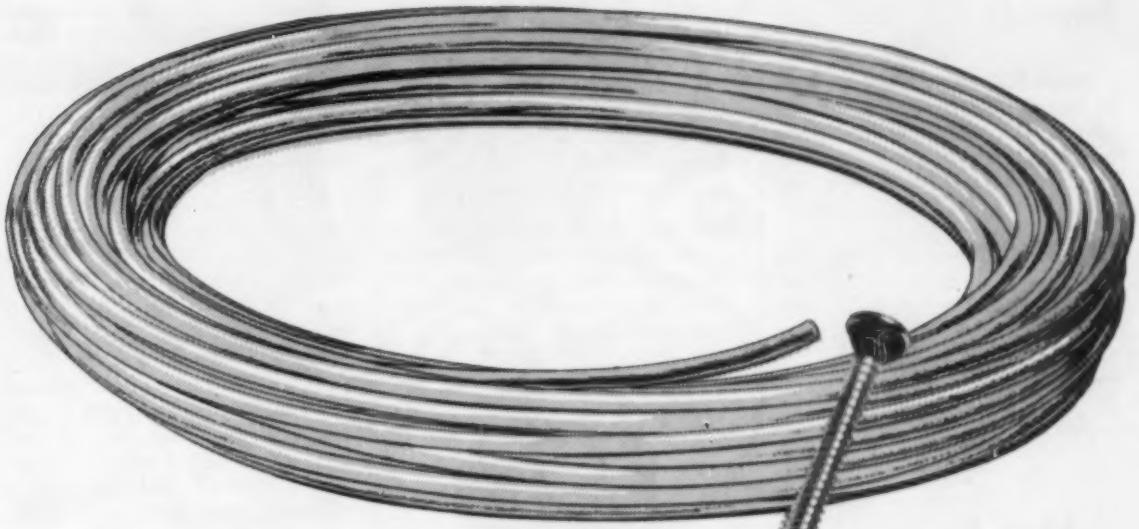

they grip tight...seal tight
—they're made of

CRUCIBLE
stainless steel cold heading wire

These *Tuff-Tite** fasteners, made by Townsend Company, New Brighton, Pa., have a neoprene washer preassembled into the head. They stop leaks . . . hold tight even where there's severe vibration . . . seal out moisture effectively.

Of course high speed production of these fasteners, like other types of screws, bolts, rivets and pins, demands cold heading wire with optimum workability. That means wire that's structurally sound and metallurgically uniform . . . with sufficient ductility to make forming easy . . . and with good tensile strength.

Crucible stainless steel cold heading wire has all these qualities — *plus* exceptional corrosion-resistance. That's why Crucible Types 305 and 410 stainless are used for the new *Tuff-Tite* fasteners, as well as for many other types of fasteners.

Crucible will fill your stainless cold heading wire needs quickly and efficiently . . . in the grade and size that best fits your application. Talk over your production requirements with your Crucible representative soon. *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

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Write now for your free copy of Crucible's new 32-page booklet on Rezistal stainless steel wire.

CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

Personals . . .

James B. Melehan, a graduate of New York University, is now employed as a metallurgical engineer in the nonferrous physical metallurgy department of Battelle Memorial Institute, Columbus, Ohio.

Donald D. Dewar is now chief of physical testing for Kaiser Aluminum and Chemical Corp., Trentwood, Wash.

Virgil B. Bullen, formerly superintendent of the process machinery laboratory at Cincinnati Milling Machine Co., Cincinnati, Ohio, has been appointed engineering representative for Tocco Div., Ohio Crankshaft Co., and will have headquarters in Chicago.

Donald A. Bergh is now an instructor in metallurgy at General Motors Institute, after having been instructor in foundry in the Muskegon (Mich.) Public Schools.

Donald C. Larson was awarded the Metal Powder Association Scholarship for the school year 1955-56. Mr. Larson is top man in his metallurgical engineering class at the University of Washington, and vice-chairman of the student chapter.

Karl Thomas Aust, **Robert H. Doremus**, and **Frank VerSnyder** have been added to the staff of the metallurgy and ceramics department of the General Electric Research Laboratory, Schenectady, N.Y., as research associates. Dr. Aust has been a research associate at Johns Hopkins University for the past three years, and previously had been a metallurgist with the Kaiser Aluminum and Chemical Corp., Spokane, Wash. Dr. Doremus received his Ph.D. from the University of Illinois in 1953, subsequently taking additional graduate study at Cambridge University in England on a Fullbright Fellowship. Mr. VerSnyder was transferred to the Research Laboratory from the small aircraft engine department of General Electric Co. in Lynn, Mass. In 1954 he was awarded the Henry Marion Howe Medal.

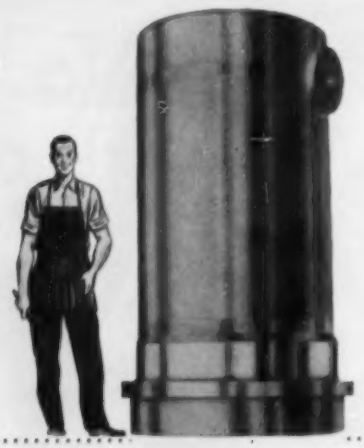
Americo M. Santoro, Jr., recently released from active duty in the U. S. Navy where he served for two years on board the U.S.S. Thomas E. Fraser as assistant engineering officer, is now employed as a product engineer in the wire and weld plant, parts division, for Sylvania Electric Products, Inc., Warren, Pa.

Douglas H. Polonis has completed requirements for the Ph.D. degree in physical metallurgy at the University of British Columbia and is assistant professor of metallurgical engineering, School of Mineral Engineering, University of Washington, Seattle.

Henry M. Miles, formerly laboratory supervisor and sales manager for Chapel Testing Laboratories, Inc., Dayton, Ohio, is now quality control laboratory superintendent for Ford Motor Co. in the new plant in Sandusky, Ohio.

Seymour Epstein is now attending Iowa State College where he is doing graduate study on a research assistantship in the metallurgy department of the Ames Laboratory of the U. S. Atomic Energy Commission.

Need Large Hydraulic Cylinders?



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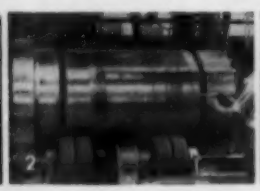
TITUSVILLE FORGE



Hydraulic cylinders combining the advantages of thoroughly hot worked steel and clean automatic welding are being furnished by Titusville. Such cylinders insure the user of better physical characteristics (hollow forged shell and flanged sections together with upset forged top or dome sections), freedom from leakage under pressure because of porosity and the complete elimination of costly repairs or rejections. Fabrication is shown in photos above.

1. Hollow forging for shell section being hot worked on mandrel.
2. Hollow and upset forgings assembled for automatic welding.
3. Complete welded cylinder being rough turned in 80" engine lathe.

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PLANTS AT TITUSVILLE, PA., and WARREN, PA.

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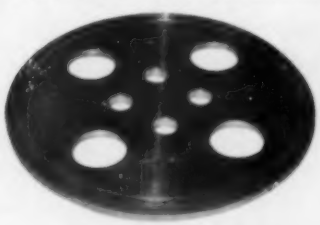
Blank size: ⅜" thick x 16½" x 23½"

Blank size: ⅜" thick x 9" x 31"

Blank size: 5" thick x 78" OD

Blank size: 4" thick x 7¾" x 71⅜".
Illustrations show before and after machining.

All the products illustrated here were flame cut, sawed, abrasive cut, sheared or machined from stainless steel plate.



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Stainless steel plate produced to your specifications for quick delivery

Confidence in Carlson service has made G. O. Carlson, Inc. the country's leading specialist in stainless steel plate. As we grew to this position in the industry, we learned and developed new methods of working stainless plate.

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It means you can buy for quick delivery exactly what you need in stainless steel plate—sheared, sawed, flame cut, abrasive cut, or machined. And this is true whether the job is a "toughy" or "run of the mill"!

When you need stainless steel plates—special patterns like these or plain rectangles—you'd better try Carlson service, where experience pays off.

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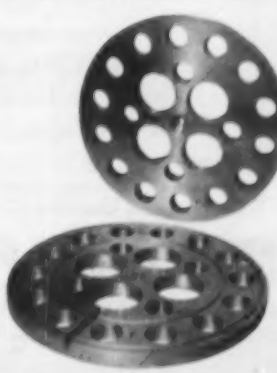
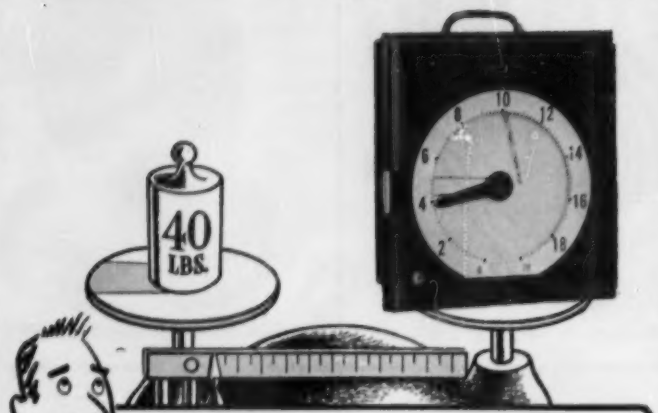
District Sales Offices in Principal Cities

Blank size: 3⅛" thick x 106½" OD

Blank size: ¼" thick x 75" x 88"



Blank size: 1½" thick x 26" OD



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In response to the increasing demand in industry for a truly portable indicating recorder, we have redesigned our standard Thermo Electronic Recorder . . . making it 18 lbs. lighter . . . without sacrificing either accuracy, sensitivity or durability.

In addition to recording temperatures in 19 standard ranges, from —100° to +100°F. up to 0° to 3000°F., it is also used to measure humidity, solution conductivity, speed, pH, direct current, DC voltage, power, strain, or any other measurement that can be converted to a change in resistance or DC millivoltage.

The simple design of the electronic balancing system of this instrument employs only three moving parts, and nylon drive gears and cam rolls are used throughout for quiet, durable operation.

A cam is used to drive the recording pen, thus permitting linear charts to be used for almost all measurements, despite the non-linearity of the sensitive element characteristics.

SPECIFICATIONS

CHART
Circular, 12" diameter, 4⅝" scale width, uniform graduations.

CHART DRIVE
Synchronous, electric, 24-hour revolution standard, other speeds available.

CALIBRATION ACCURACY
±¼ of 1% of scale span.

BALANCE CONTROL ACTION
Continuous null, positive drive of slidewire and pen, no galvanometer, unaffected by vibration.

SENSITIVITY
One slidewire turn (less than ±1/20 of 1% of scale).

DIMENSIONS
16⅞" wide by 18⅜" high by 7½" deep.

NET WEIGHT
40 lbs.

Interested?
Write for catalog Section 60-100-H covering this latest addition to the growing T-E line.

We have openings for qualified sales engineers and design engineers with electro-mechanical or instrument experience. Include resume with letter of application. Salary commensurate with experience.

Pyrometers • Temperature Monitoring Systems • Thermocouples • Protection Tubes
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SADDLE RIVER TOWNSHIP, ROCHELLE PARK POST OFFICE, NEW JERSEY
IN CANADA—THERMO ELECTRIC (Canada) Ltd., BRAMPTON, ONTARIO

Personals . . .

W. A. Hammer is now manager of the screw department for National Ventilated Awning Co., Dallas, Tex.

Murray J. Granger, formerly with Aerojet-General Corp., Azusa, Calif., is now plant manager of the Montebello, Calif., works of Wall Colmonoy Corp.

John F. Elliott was recently appointed associate professor of metallurgy at Massachusetts Institute of Technology, where he will teach metallurgy and continue his work in the process metallurgy of iron and steel and the thermochemistry of metal systems. Dr. Elliott was previously employed as assistant superintendent in the open-hearth and blooming mill, quality control department, Inland Steel Co.

Paul P. Combs, formerly with Southwestern Ohio Steel, Inc., Hamilton, Ohio, is now employed as cold mill metallurgist for McLouth Steel Corp., Trenton, Mich.

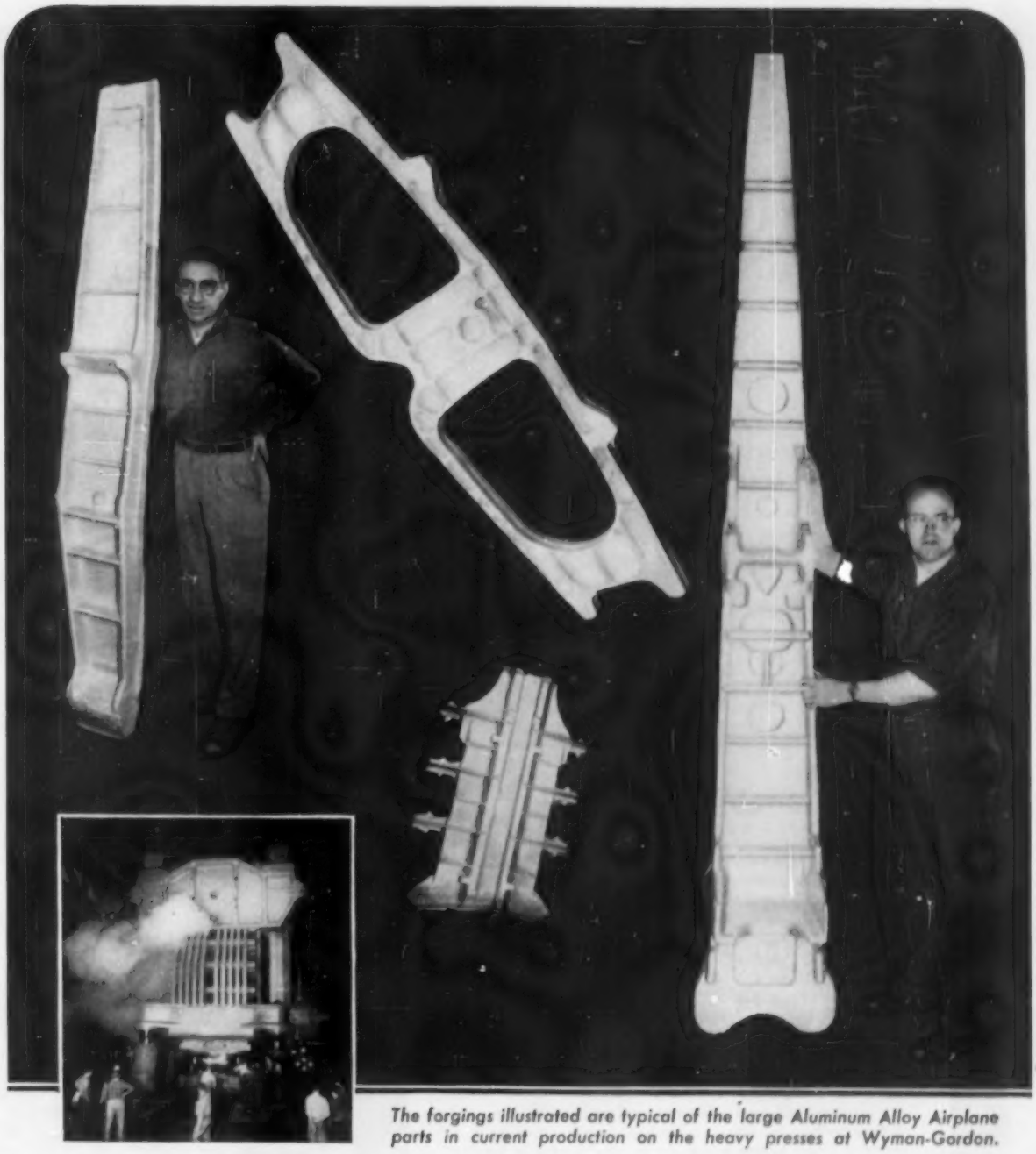
J. L. Eirls has resigned as foreman of the heat treating department at Food Machinery and Chemical Corp., San Jose, Calif., to accept a graduate teaching fellowship in the physics department at Colorado School of Mines, where he is working toward an M.S. degree in mining engineering.

Richard Raring, formerly a metallurgist with the U. S. Naval Research Laboratory, is now with the National Advisory Committee for Aeronautics, Washington, D. C.

W. W. Culbertson, previously director of industrial liaison at Case Institute of Technology, is now a member of the manager's staff at Bettis Field, Westinghouse Electric Corp., Pittsburgh.

A. L. Hodge, research metallurgist of Linde Air Products Co., has been transferred from the research laboratory at Tonawanda, N. Y., to the development laboratory, Newark, N. J., as consulting metallurgist in iron and steel process metallurgy.

James E. Fifield is now employed as a staff metallurgist for International Selling Corp., New York City.



The forgings illustrated are typical of the large Aluminum Alloy Airplane parts in current production on the heavy presses at Wyman-Gordon.

A new era in the art of forging has been demonstrated as production goes forward on this 35,000-ton closed die forging press. Larger forgings with thinner sections and closer tolerances than heretofore possible open new concepts in forging design. Wyman-Gordon continues to pioneer by — Keeping Ahead of Progress.

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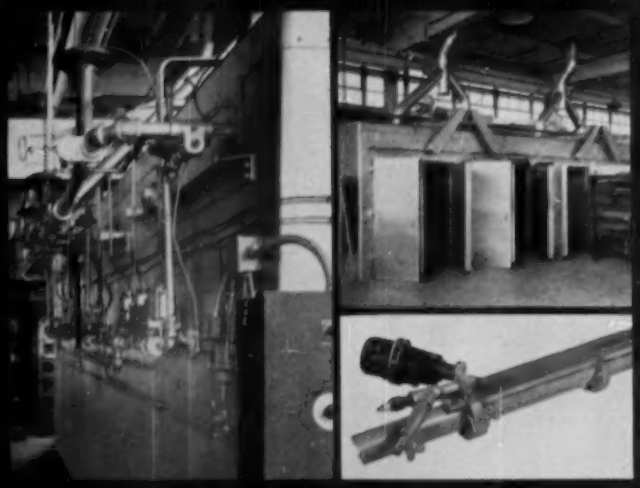

Sand Core Drying Ovens
by Michigan Oven Co., Detroit

Eclipse Combustion Equipment was specified for the above sand core drying ovens by Michigan Oven Company of Detroit and Greenlee Bros. & Company of Rockford. It was agreed that Eclipse offered the most complete line of combustion equipment available, and there was the added advantage of dealing with a single responsible source. All 11 ovens installed in the Rockford plant of Greenlee Bros. & Company are equipped with complete Eclipse gas burning combustion assemblies.

Engineered and built specifically for this job, two types of ovens were installed. One was of "lift rack" design and approximately 6 ft wide, 7 ft deep, and 7 ft long. Two banks of four ovens of this type were used. The other type, "large car" ovens are 12 ft wide, 19 ft deep, and 8 ft high (one set of three). All ovens are operated 16 hours a day, at a temperature of 425 F which is maintained exactly. Although the ovens are installed in sets, each is independently controlled and completely flexible as to operating temperature and time cycle.

Air is recirculated through the ovens and because of its velocity Eclipse line burners were selected for their flame retention characteristics. Other Eclipse equipment includes: Lock-Tite Safety Shutoff Valves, Zero Gas Governors, pilot assemblies with flame protection, blast gates, and LP mixing tees.

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Eclipse Fuel Engineering Co. of Canada, Ltd., Don Mills, Ontario

Eclipse COMBUSTION EQUIPMENT

Personals . . .

Victor F. Zackay, research engineer for Ford Motor Co., Dearborn, Mich., has been promoted to supervisor, physical metallurgy section, in the metallurgy department at the Scientific Laboratory.

W. F. Anderson has been appointed district representative in the Chicago area for Ohio Forge and Machine Corp., Cleveland.

Ronald A. Kelsey, an employee of Electric Boat Div., General Dynamics Corp., is attending the Oak Ridge School of Reactor Technology at Oak Ridge National Laboratory.

Eli Margolin is now a technical engineer in the Evendale Plant of General Electric Co., Cincinnati, Ohio.

Walter E. Simon, previously with the Imperial Smelting Corp., Chicago, is now in charge of plant operations at George Sall Metals Co., Philadelphia.

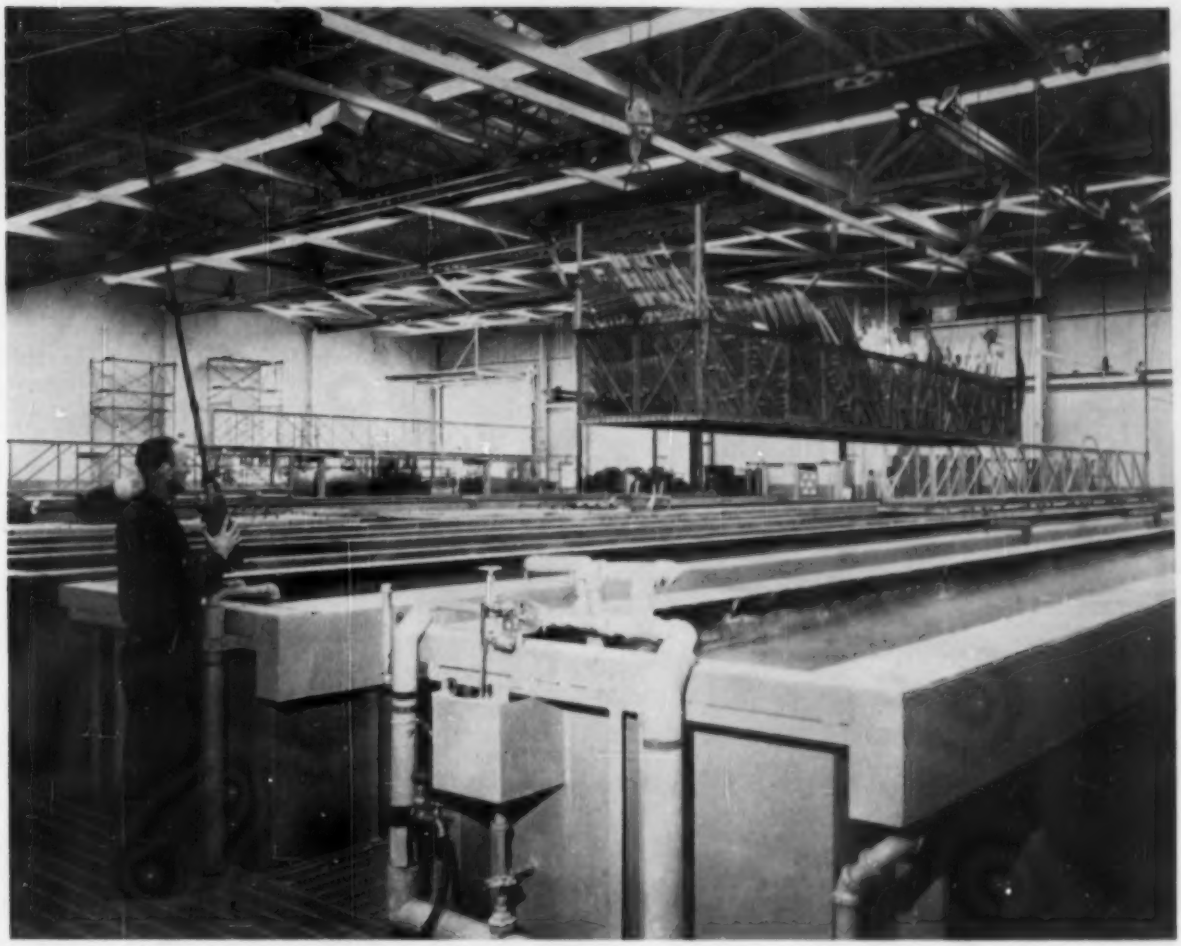
William H. C. Webster, formerly district sales manager, has been appointed assistant general manager of sales of coated sheet products for Weirton Steel Co., a division of National Steel Corp.

F. L. Orrell is now supervisory engineer of fuel element development in the reactor department, atomic power division, Westinghouse Electric Corp., Pittsburgh.

P. C. Mortinson has been transferred by Massey-Harris-Ferguson, Inc., from Racine, Wis., where he was executive engineer, to Detroit, and appointed administrative engineer, western hemisphere. Mr. Mortinson was employed by the company in 1950 as director of research.

Alfred P. Schneller, Pacific Coast sales manager for the welding products division of A. O. Smith Corp., has been made eastern regional sales manager for the division.

Rodger D. Veneklasen, formerly furnace project engineer with the equipment division of National Research Corp., Boston, has joined General Communication Co. in the same city as assistant chief metallurgist in the newly created metallurgical development division.



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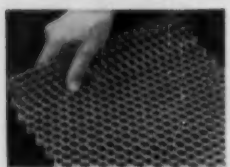

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Personals . . .

Sheldon Weinig has received the Ph.D. degree from Columbia University, where he was lecturer in physical metallurgy, and has been appointed assistant professor of physical metallurgy in the College of Engineering at New York University.

Charles D. Smith has accepted a position with the reactor development division of Combustion Engineering, Inc., New York, and is in charge of metallurgical activities for the division.

John J. Adams, formerly plant metallurgist at Fischer Casting Co., Inc., North Plainfield, N.J., is metallurgical engineer for the Crystal Products Div., Tung-Sal Electric, Inc., Bloomfield, N.J.

D. T. Goettge, previously chief sheet mill metallurgist and inspector, Fairless Works, United States Steel Corp., has been transferred to the Irvin Works, Dravosburg, Pa., as assistant chief metallurgist and inspector.

George C. Wheeler, Jr. recently accepted the position of senior materials engineer, SIR Project, at the Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N.Y. Mr. Wheeler was formerly employed as metallurgical engineer in the Fitchburg Works, and supervisor of nondestructive testing in the River Works, both of General Electric Co.

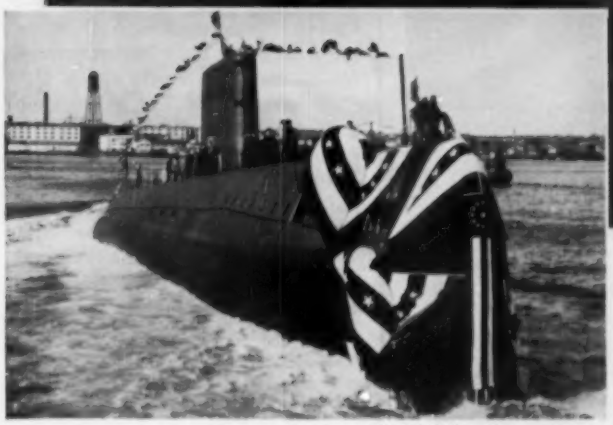
Floyd E. McBride is employed as a metallurgical engineer in the materials section, aircraft nuclear propulsion department, General Electric Co., at the Evendale plant in Cincinnati, Ohio.

Alfred A. Wald is now plant-wide maintenance superintendent at Caterpillar Tractor Co., Peoria, Ill.

Charles R. Cook, Jr. has resigned as senior research engineer with Titanium Metals Corp., Henderson, Nev., to accept the position of project engineer with Thompson Products, Inc., Cleveland.

Milton J. Alexander, formerly chief metallurgist for Quaker State Metals Co., Lancaster, Pa., has accepted a position as process control engineer at the magnesium plant of Dow Chemical Co. in Madison, Ill.

MIDVALE FORGES STAINLESS STEEL



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Vanadium Pentoxide Attack on Heat Resisting Metals*

A VALUABLE investigation of the old and troublesome problem of corrosion of metal surfaces exposed to V_2O_5 deposits at high temperatures is described. This work involved the determination of the softening and melting points of various mixtures of V_2O_5 with the common high-melting metal oxides, Al_2O_3, BeO, CaO, Co_3O_4, Cr_2O_3, NiO, MgO, CuO, Fe_2O_3 and ZnO. The purpose of the research was to determine if any mineral additives could be made to fuels containing traces of vanadium which would form high melting point compounds with V_2O_5. This might reduce the tendency of low-melting V_2O_5 to react with oxide films on hot turbine blades and superheater tubes.

A variation of the seger cone method for determining the melting point of coal ash was used in this investigation. Varying proportions of the metal oxides which have high melting points were mixed with V_2O_5, ball milled, moistened and molded into cones. Two cones were prepared from each binary mixture. All mixtures contained 5 to 90% high-melting oxide in 5% increments.

Cones prefired at 1020° F. were placed upright in the furnace and heated. The temperatures at which the tip of the cone first started to bend over, and at which the tip touched the support were recorded.

A series of ten plots with the per cent of metal oxide plotted against temperature trace the approximate melting point of all the metal oxide-V_2O_5 mixtures. The melting point of V_2O_5 was taken as 1238° F. The Al_2O_3-V_2O_5 mixture showed no increase in melting point until 50% Al_2O_3 was reached and this gave a melting point of 2012° F. The MgO and NiO mixes gave the most rapid increase in melting point, 25% MgO giving 1724° F. and 40% MgO giving 2012° F.

Following this work, which showed that large amounts of refractory oxide would need to be

*Digest of "The Liquidus of Metal Oxide, V_2O_5 Systems", by G. Lucas, M. Weddle, and A. Preece, *Journal* of the Iron and Steel Institute, Vol. 179, April 1955, p. 342 to 347.

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heat treat under high vacuum at temperatures up to 2000°F ...in gas-tight Inconel retorts

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Inconel* keeps retorts *gas-tight*

According to the builders, proper operation of these high vacuum furnaces calls for gas-tight retorts. They must be so nonporous that it would take 120 years for a thimbleful of air at atmospheric pressure to leak in.

They must *stay* gas-tight, too . . . and keep shape despite pressure . . . despite temperatures to 2000°F . . . despite the tremendous thermal shocks of water-spray cooling . . . despite oxidation, carburization and other forms of attack.

Inconel nickel-chromium alloy is able to handle such an assignment. It has given as much as 5000 hours in these high vacuum retorts without sign of failure.

You may be looking for an alloy like this . . . with high and lasting hot strength plus corrosion resistance. If so, look into Inconel. A new Inco booklet, "Keep Operating Costs Down When Temperatures Go Up", pictures many ways to use Inconel effectively. Write for a copy.

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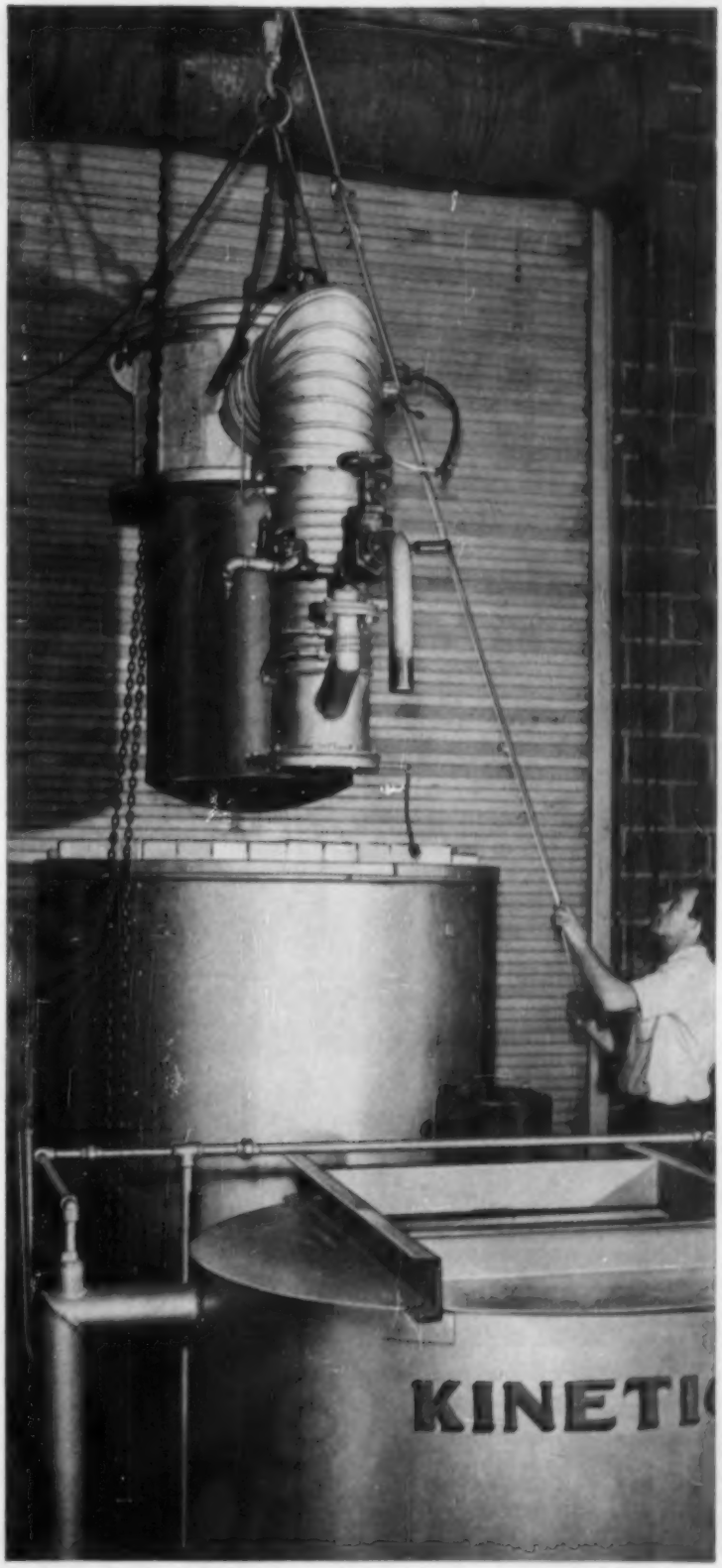
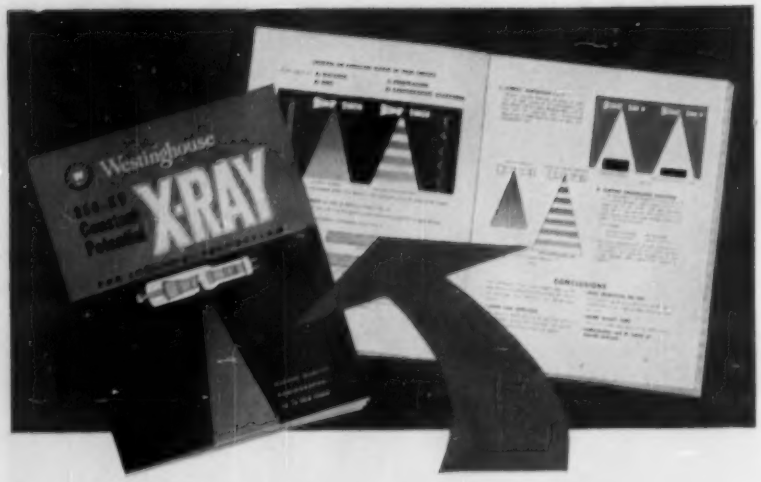


Loaded Inconel Retort and part of vacuum producing equipment are lowered into combustion chamber of new vacuum furnaces for heating. After heat treatment, retort is spray cooled in tank in foreground. Despite thermal shock Inconel retort stays gas-tight.



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Vanadium Pentoxide . . .

added to fuels containing V_2O_5, a study was made of the effect of adding V_2O_5 deposits to metal surfaces when exposed to temperatures of 1290° F., slightly above the melting point of V_2O_5. Since most heat resisting alloys contain large amounts of chromium, cobalt and nickel, oxidation tests were made on these pure metals and some alloy combinations such as 80% Fe, 20% Cr; 80% Co, 20% Cr and 80% Ni, 20% Cr.

The oxidation tests were carried out by suspending a sheet of the metal (1 cm. square) from the arm of a balance which was outside the furnace, and was arranged to draw a curve on photographic paper as the specimen increased in weight due to oxidation. The temperature of 1290° F. was chosen so that the V_2O_5 would be molten but not sufficiently volatile to affect the results. Since the pure metals and alloys studied oxidize only slightly in air at this temperature the influence of small deposits of V_2O_5 on the surface could be followed. About 0.05 mg. of V_2O_5 was deposited on each sample. At the end of the test on electrolytic chromium it was found that a dark green scale covered the complete surface, indicating that the minute amount of V_2O_5 had spread by diffusion to all parts of the specimen. The total gain in weight was about 5 mg. The sample with no V_2O_5 deposit showed practically no gain in weight after two weeks at 1290° F. This oxidation process on the chromium surface obviously follows the equilibrium diagram of the Cr_2O_3-V_2O_5 system previously surveyed with the seger cone tests. The reaction occurs in four steps as follows:

1. Presence of liquid scale film high in V_2O_5.
2. Appearance of solid scale film, melting at 1650° F. when Cr_2O_3 content of scale exceeds 20%.
3. Scale containing $CrVO_4$ vanadates in the region of 30 to 45% Cr_2O_3.
4. Further oxidation of the metal surface to give a scale containing over 95% Cr_2O_3.

Since the test temperature was 1290° F., the scales formed were at a temperature well below their melting points and the continuing oxidation took place by diffusion of oxygen through this solid film triggered

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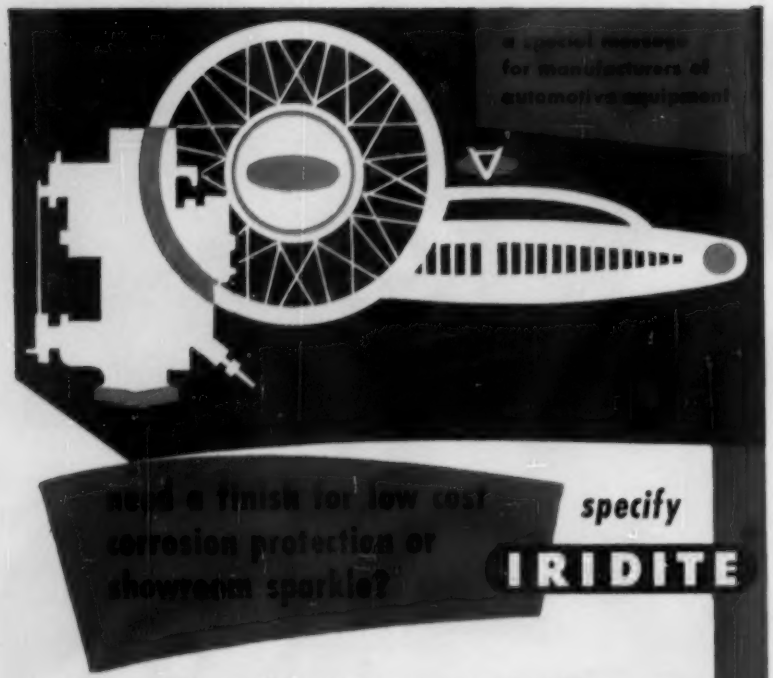

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Vanadium Pentoxide . . .

by the minute amount of V_2O_5 present on the surface.

It is therefore apparent that the oxidation of pure chromium is radically changed to a curve of parabolic form in the presence of V_2O_5. The slowing down of the oxidation is apparently due to the effect of scale thickening rather than to dilution of the minute amount of V_2O_5.

Further tests on the alloys of iron, cobalt and nickel, each with 20% Cr, showed that these alloys oxidized in air (without V_2O_5 present) at rates proportional but lower than the oxidation of the pure metals. When V_2O_5 was deposited on the alloys the rate of oxidation was increased more than five times. The order of decreasing oxidation was the iron alloy, cobalt alloy and nickel alloy.

It is clear from the results of this investigation into the mechanism of vanadium pentoxide attack that a heat resisting alloy depending on chromium for its oxidation resistance is not capable of withstanding attack by vanadium pentoxide unless some means of preventing the solution of vanadium ions in the chromic oxide film is found. It seems that successful fuel additives for this purpose would be materials which form compounds more unreactive than normal vanadates. E. C. WRIGHT

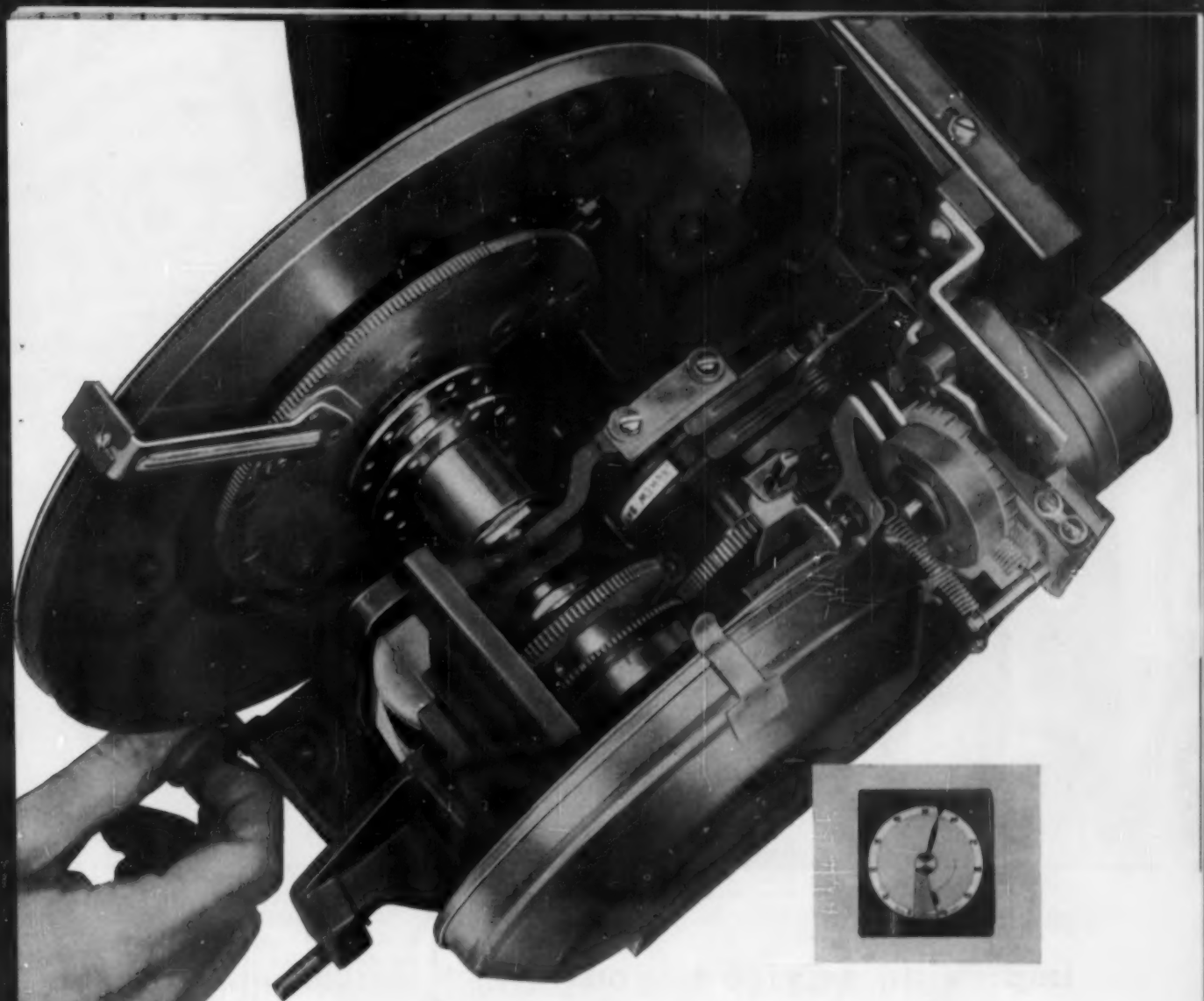
Protective Coatings . . .

(Starts on p. 96)

metallic coatings (Chapters 3 through 12), *(d)* organic coatings (Chapters 13 through 15), and *(e)* miscellaneous topics (Chapters 16 through 18).

The first part is a general review of the electrochemistry of corrosion. Since whole volumes have been written on the material covered in this 20-page chapter, thoroughness is not to be expected but the principal points are covered and it serves as an excellent introduction.

The second part covers the main methods of cleaning metal surfaces preparatory to application of the coating. The principal criticism of this chapter is that it is too short. It is not recognized as generally as it should be that the performance of metallic and organic coatings depends on the proper preparation of



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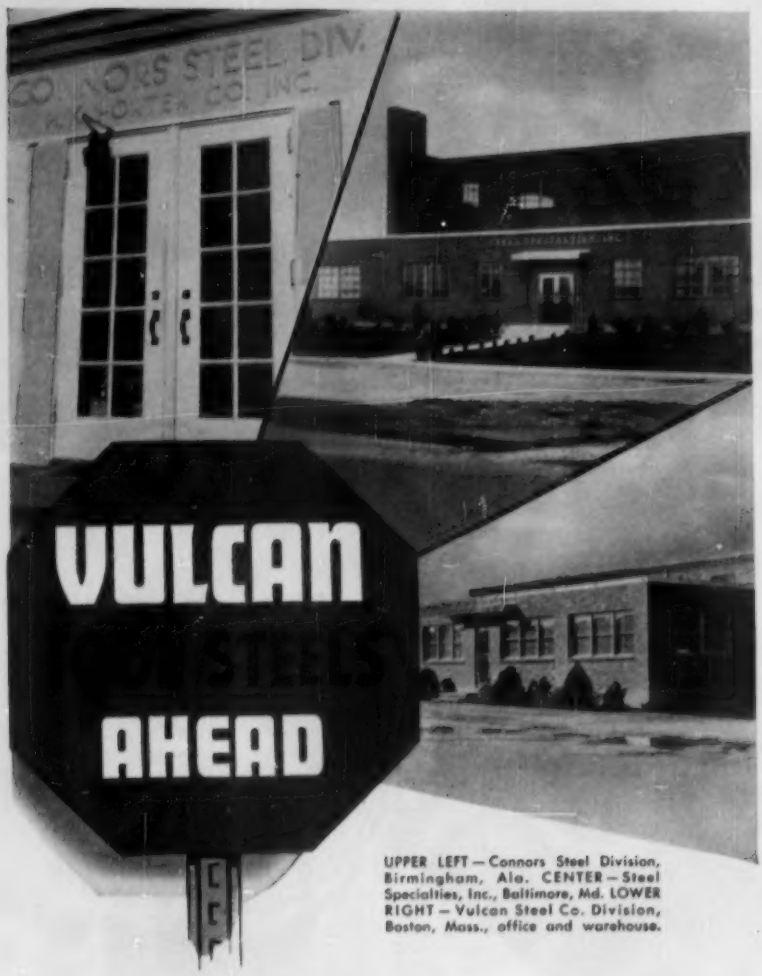

UPPER LEFT — Connors Steel Division, Birmingham, Ala. CENTER — Steel Specialties, Inc., Baltimore, Md. LOWER RIGHT — Vulcan Steel Co. Division, Boston, Mass., office and warehouse.

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Protective Coatings . . .

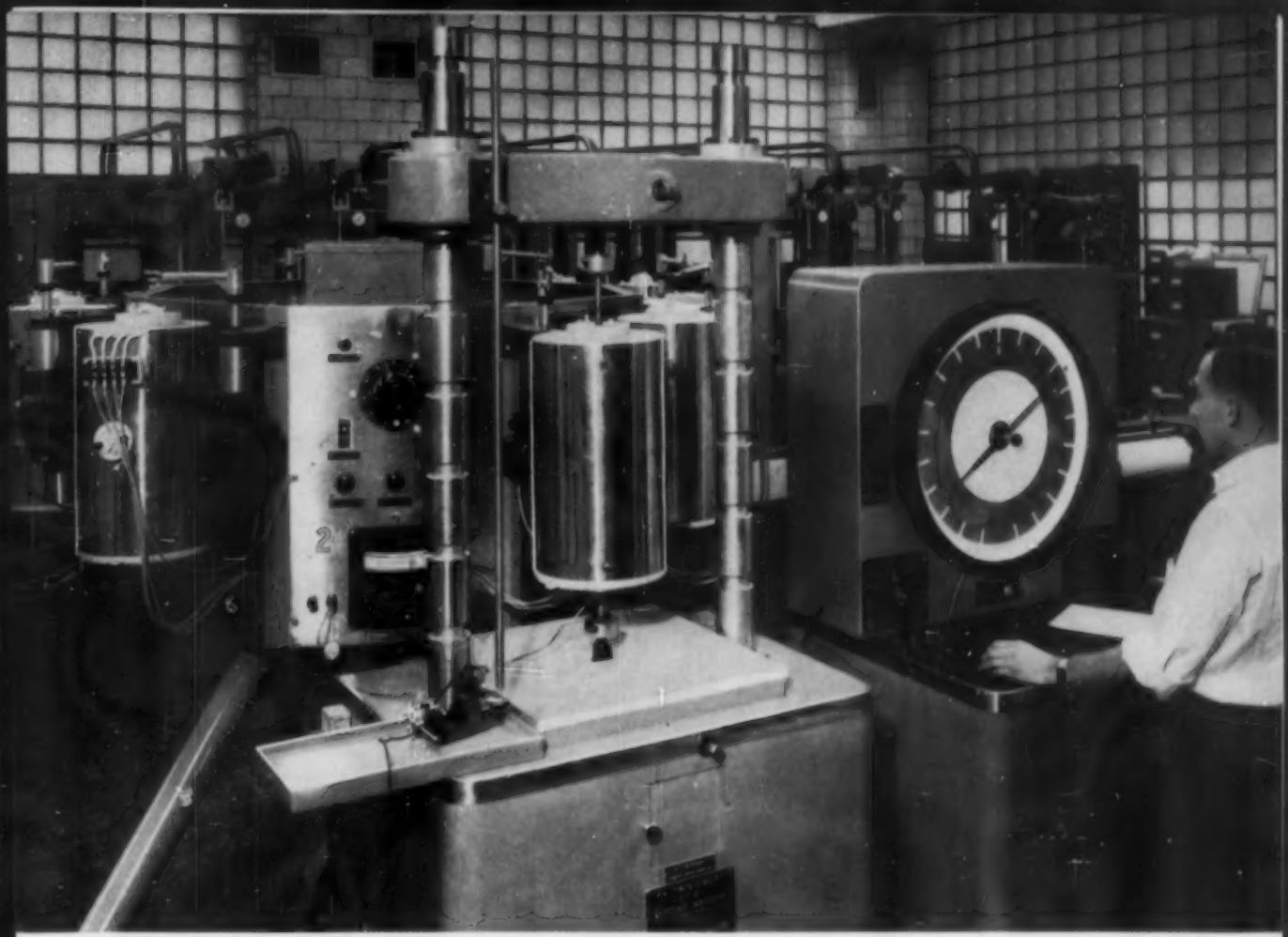
the basis metal, and that the best paint or lacquer, or the most painstaking plating job, can be ruined by improper prior cleaning. This chapter is only 18 pages long and, in addition to cleaning proper, it includes a discussion of polishing and buffing (including electropolishing), and a section on tests for cleanliness, many of which are of laboratory rather than practical interest. In the reviewer's opinion, more emphasis could have been put on the important subject of surface preparation.

With the third part (bearing in mind that this division into parts is the reviewer's, not the authors') we come to the meat of the book — a general discussion of the methods of applying metallic coatings, followed by chapters which discuss the common coating metals individually in detail. The less common metals and various alloy coatings are considered and this section concludes with an excellent chapter on methods of testing the performance of these coatings and of evaluating them. The discussion of outdoor exposure and accelerated testing is particularly good, and should be required reading for those whose sole criterion of performance is the salt-spray test.

The last two parts consider similarly the chemistry, performance and application of organic coatings, and the special topics of chemical conversion coatings, rust preventives, vitreous enamels, and inhibitors.

It is not possible to comment on each of these chapters individually but detailed examination of those sections which the reviewer feels particularly competent to judge revealed a gratifying absence of errors and, on the positive side, an excellent summary of the properties, applications, performance and testing of metallic coatings. Literature references as late as 1954 were found, but for practical purposes the book may be said to be approximately up to date as of December 1953.

No book is perfect, and a few comments on the less praiseworthy aspects will not detract materially from the general excellence of this one. Although in Chapter 1 the authors are careful to use the term "basis" metal in accordance with best present usage to mean the metal being coated (as differentiated from



New "all-electric" Baldwin SR-4® Testing Machine at Universal-Cyclops

measures electrically both tensional loads and strain on "SUPER ALLOYS" at 2200° F.

In the modern laboratory of Universal-Cyclops Steel Corporation, Bridgeville, Pa., "super alloys" for high temperature service are being tested at 2200° F. by a unique new Baldwin machine. Model FGT SR-4 is electrically powered and measures electrically both applied tensional loads and resulting specimen strain.

SR-4 load cells at the bases of the two columns sense loads up to 50,000 lb. in tension or compression. These cells control both the load indicating pointer and the recorder pen movement.

Strains of 0.160 in. diameter, 1-in. gage length button-head specimens, measured by a SR-4 type extensometer are transmitted electrically to the recorder. Close control of the strain rate is an important factor in these high temperature tests. The FGT's motor drive's loading control can be regulated to vary testing speeds from 0.025 to 9.0 in. per minute.

Univeral Cyclops is using an ingenious rotary jig to speed up greatly the frequency of tests at elevated temperatures. Eight electric furnaces on this jig heat test specimens simultaneously. Each is swung into testing position with a minimum of delay. This revolutionary new testing machine can give you automatic load reversal, creep tests, stress relaxation tests, shock tests as well as simple tension and compression. For complete detailed information please write today for Bulletin No. 4206. Address Department 2724, Baldwin-Lima-Hamilton Corporation, Philadelphia 42, Pa.

BALDWIN BLH LIMA-HAMILTON

TESTING HEADQUARTERS

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2700-lb.
Job-Engineered Muffle
demonstrates value
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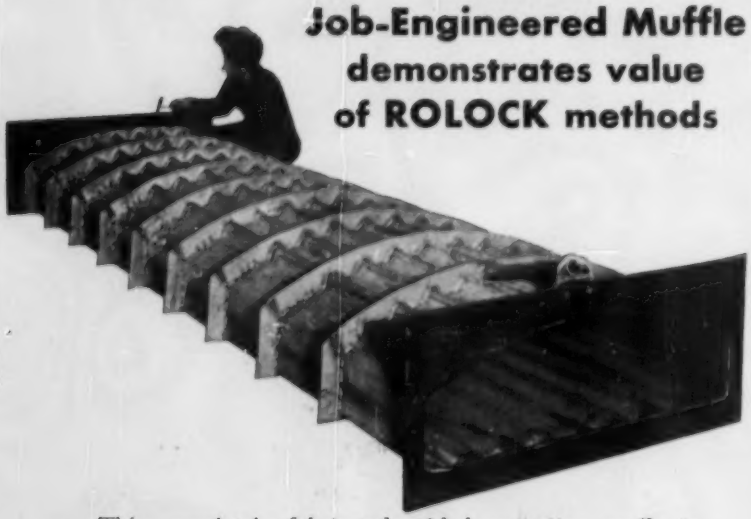

This completely fabricated-welded annealing muffle is 13'10" long, 14" high inside, and 48" wide. The material is 5/16" Inconel. It is used for continuous annealing of copper and brass tubes at 1600°F. in a Rockwell muffle furnace.

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Protective Coatings . . .

"base" metal meaning opposite of noble), in later chapters this distinction is allowed to lapse and the terms "basis" and "base" seem to be used indiscriminately. A small point, perhaps; but what is one to make of the statement (p. 51) about the veneering of base-metal plate with noble metals, when the term "base metal" is being used in both senses?

One lack which this reviewer felt keenly was the absence of a chapter – one which these authors would be in an excellent position to write – on choosing the proper coating for a given job. If the reader wishes to learn the properties and applications of any given coating (zinc or cadmium or nickel, vinyl or what not), he need only turn to the appropriate chapter, but if the problem is turned around – how to select an appropriate coating for a given exposure – he would be forced to leaf through each chapter, on each individual coating, to find the answer; nor would the otherwise good index be of assistance. The pleasure and profit gained by reading the book are not thereby decreased, but its value as a reference is somewhat impaired.

Of actual errors or omissions the reviewer could find only one of any consequence. In the discussion of tin-copper alloy coatings (p. 268) no notice has been taken of the use of red bronze as an undercoat for nickel-chromium platings, published at least as early as 1952 and of increasing interest since then.

To sum up, this book is an excellent compendium of accurate and up-to-date information on the properties, applications, performance and testing of metallic and organic coatings used for the protection of metals. In the field of metallic electroplated coatings it is no substitute for the more detailed information given in such books as "Modern Electroplating" or the "Electroplating Engineering Handbook"; similarly, corresponding works are available in the field of organic coatings. But as a survey of the whole subject it is unexcelled and will probably remain so for some time. It should be of great value to designers, engineers, metallurgists – anyone concerned with protecting metallic parts or structures from corrosion.

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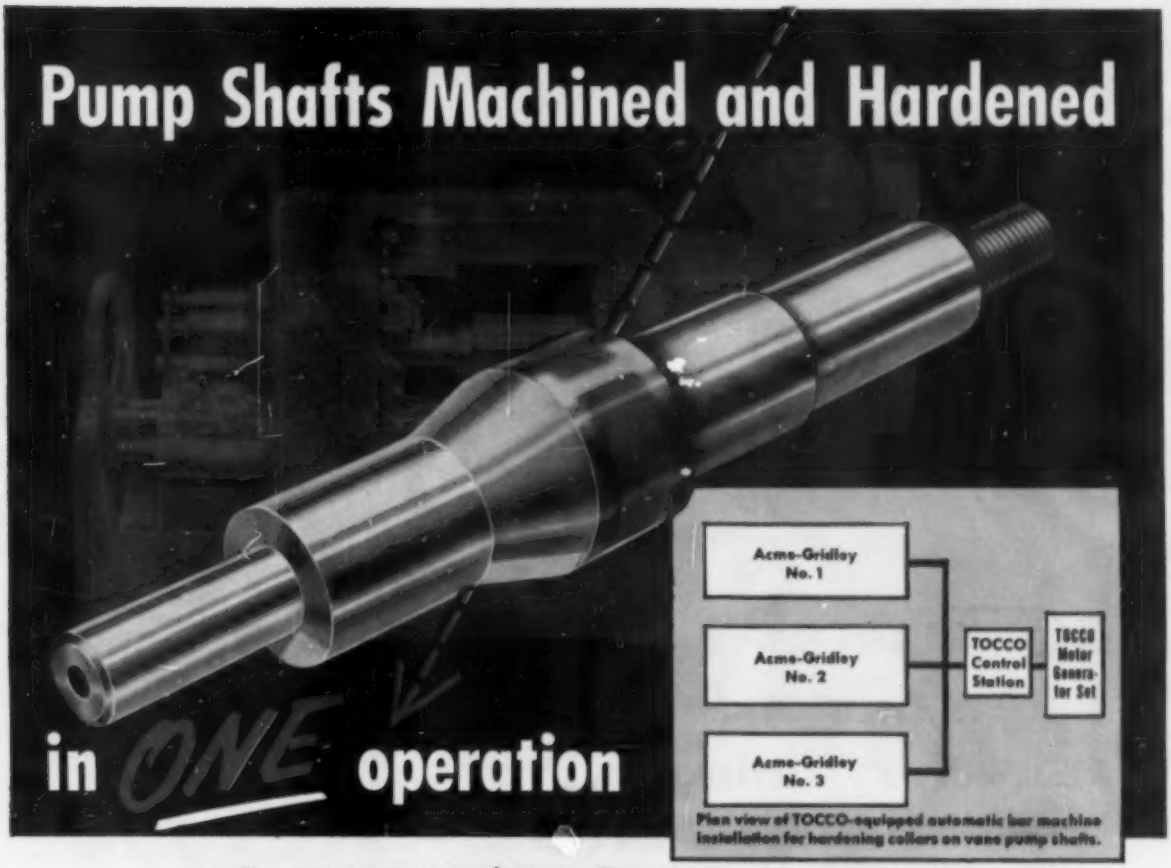

Plan view of TOCCO-equipped automatic bar machine installation for hardening collars on vane pump shafts.

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Blazecrete* linings last longer because they resist spalling, withstand slagging action, and are not harmed by rapid temperature changes.

Thus you cut down on refractory maintenance costs—and you save on labor costs, too, because Blazecrete goes on fast. For troweling, just mix Blazecrete with water as you'd mix ordinary concrete . . . then slap-trowel it in place. When gunned, it adheres readily with a minimum of rebound loss. Either way, Blazecrete may be applied easily without laborious ramming or tamping.

Three types of hydraulic-setting Blazecrete are available. All harden on air curing, do not require prefiring. They are furnished as a dry mix—can be stored safely for use as needed.

3X BLAZECRETE—For temperatures through 3000F. Unusually effective for heavy patching, especially where brickwork is spalled or deeply eroded. Excellent for forge furnace linings, lime kilns, burner blocks, soaking pits, and industrial boilers.

STANDARD BLAZECRETE—For temperatures through 2400F. Makes repair work easier and less costly. Can be used by boiler manufacturers to replace fire clay tile in wall construction. Suitable for use in combination with 3X Blazecrete and L. W. Blazecrete.

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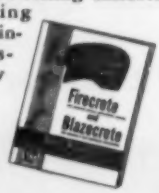
Send for Brochure RC-28A on Blazecrete and its companion material, Firecrete*. . . the hydraulic-setting castable refractory for making special shapes and linings. Write Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay St., Toronto 1, Ontario.



Whether you gun it... *or slap-trowel it...*

Johns-Manville **BLAZECRETE**

BUILDS BETTER REFRACTORY LININGS

Toughness . . . (Starts p. 112)

these steels have led to the first limited approval by the A.S.M.E. Boiler and Pressure Vessel Committee for their use in pressure vessels.

Stainless steel containing about 12% chromium and 0.1% carbon, Type 403, is widely used in the tempered martensitic condition as turbine blading.

Precipitation-hardened stainless steels probably stand at the highest commercial alloy end of low-carbon martensites. Many of these involve three-stage treatments: an austenite conditioning treatment, transformation to martensite and additional hardening of the martensite by precipitation of another phase. Several such steels are based on modifications of the basic Type 301 (nominally 17% Cr, 7% Ni and 0.1% C).

Type 301 itself is very widely used as a high-strength constructional steel in the lightweight transportation industry. When cooled from high temperature, it is normally austenitic at room temperature. It is, however, so unstable that it very readily transforms when plastically deformed; and as this transformation occurs by the martensitic mechanism, the product is really low-carbon martensite though commonly termed ferrite.

In summarizing this survey of low-carbon martensites two unique characteristics are paramount:

1. The high-temperature range of martensite formation leading to Q-tempering during quenching results in less residual stress, less distortion because volume change at transformation is less, and very little retained austenite, thereby virtually avoiding delayed hardening stresses.

2. Cementite, which begins to form during Q-tempering, is the first and, at present knowledge, the only carbide formed on tempering except for alloy carbide in higher alloy steels.

Low-carbon martensites combine strengths up to 200,000 psi. with excellent toughness and optimum combination of flow resistance and ductility. These properties, when adjusted to suitable formability and weldability, and enhanced in some stainless steels by exceptional corrosion resistance, make low-carbon martensites among the most versatile of steels.

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"Increased tool life 50%, lowered production costs," says the Toledo Pressed Steel Company. Fabricating 600 to 700 tons of steel per month, Toledo Pressed Steel is one of the largest stamping companies in Toledo, Ohio. From its 78 punch and draw presses, ranging from five to 500 tons, come truck flares, road construction torches, radio and television parts, and stampings for the automotive industry.

Volume operation? You bet! . . . the kind where the right lubrication makes a big mark in the profit column. And the right lubrication for Toledo Pressed Steel has been Cities Service Lubrication.

Says Plant Manager Walter Baird: "We have been using Cities Service drawing oils for nine years on all drawing and stamping operations. Previously we used several different compounds. But now with Cities Service drawing oils, we have increased tool and die life 50%, which, of course, has lowered production costs. In addition, they have reduced die maintenance labor costs about 25% compared to our former oils, and offer the bonus of easy removal from stampings where plating is necessary."

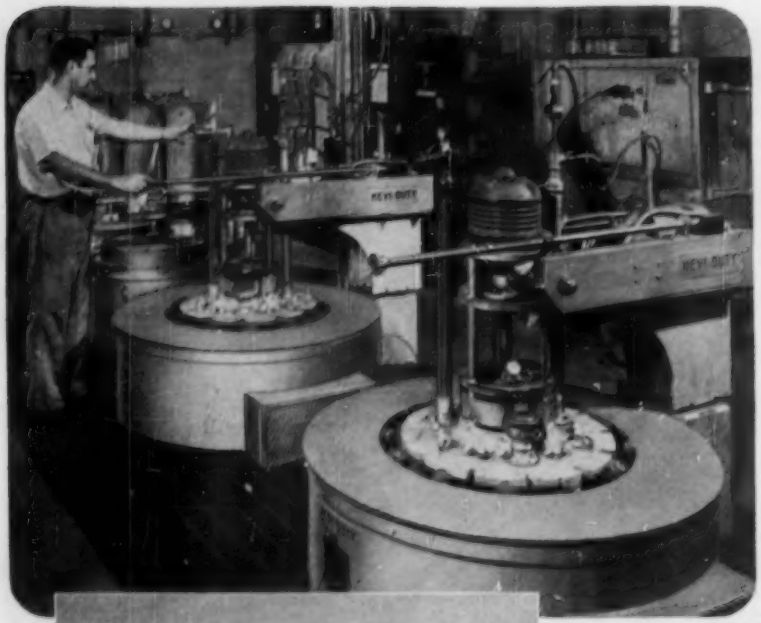
A Cities Service Lubrication Engineer can help you achieve similar results in your operation. Why not call him in. Or write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.

Road Construction Torches are one of the many products of Toledo's 78 punch and draw presses. These torches cost less to produce due to firm's use of Cities Service drawing oil.

Plant Manager Walter Baird with some of company's products . . . construction flares, metal stampings for automotive manufacturers and numerous radio and television parts.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS



Typical parts heat treated in Hevi Duty furnaces at the Union Special Machine Co.

UNION SPECIAL
heat treats precision parts in
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Walter Weinwurm, chief metallurgist at Union Special, says "Our Hevi Duty furnaces do an exceptionally good job of heat treating precision parts. The work comes out of the furnaces clean with no scale or oxidation."

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Dry Type Transformers *Constant Current Regulators*

Evolution of Efficient Immersion Pyrometers for Openhearths*

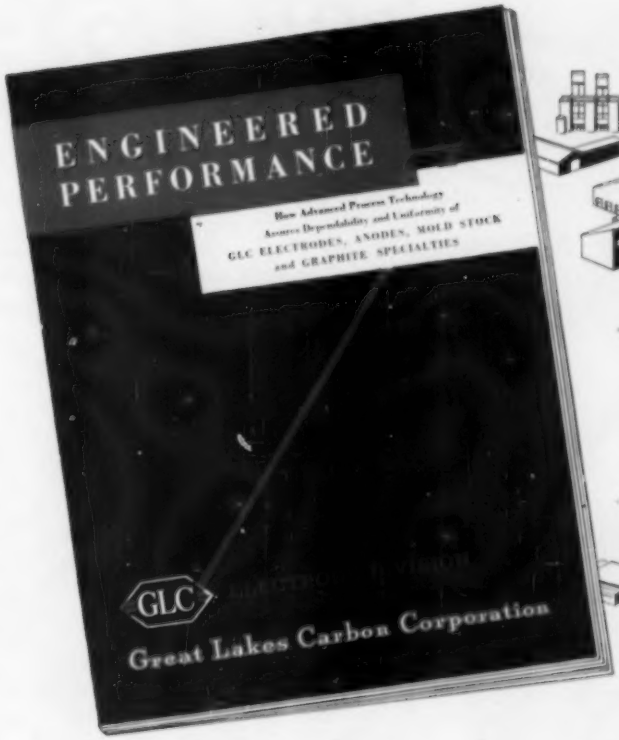
DEMAND for more frequent temperature readings at "slag off" during refining and at tapping of openhearth furnaces has forced the improvement of immersion pyrometers at the Appleby-Frodingham Steel Co. in Great Britain. The seven-furnace Appleby shop, for instance, currently schedules over 12,000 readings annually from its six pyrometers on three-shift service. Additional temperature checks are being required before slag-off in baths which are relatively cold, necessitating prolonged immersion of the pyrometer to obtain a steady reading, thereby further increasing the service requirements of the equipment.

Principal challenge has been to find a suitable stable electrical insulation which could be applied to the thermocouples to minimize maintenance. Early designs had reels of reserve platinum and platinum-rhodium wire at the handle end, with the wires running down glass fiber sleeves in the body tube to the immersion end. Here they were bent at right angles in glass tubing packed in asbestos wool. The silica body tube was insulated by first wrapping with 1 × 1-in. steel wire mesh over which was pasted a ½-in. layer of refractory cement.

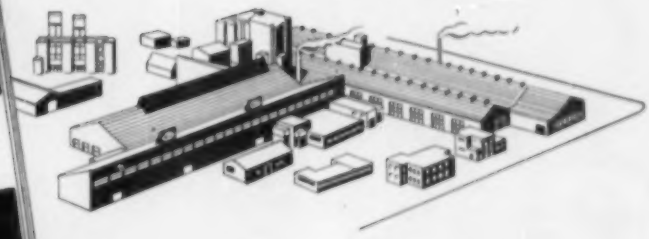
Several improvements followed quickly on this initial arrangement. Wire contamination was reduced by designing a steel liner tube to prevent the wire being affected by the reducing atmosphere of the carbon block housing at the immersion end. In addition, all steel components were degreased and annealed in air before use to remove all oil or grease as sources of sulphur. Asbestos wool used to ram the sheath or dipping tube was burned off at about 900° F. before insertion.

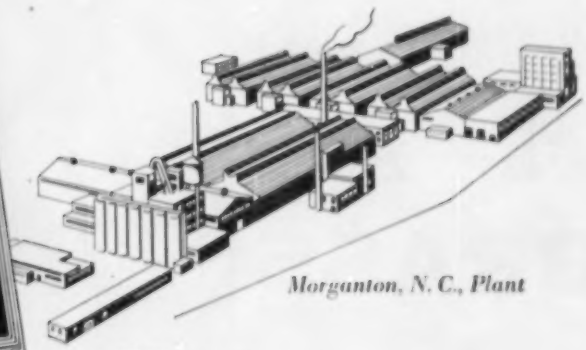
The most prevalent cause of "no readings" was shorting, resulting from the wires penetrating the glass fiber sleeve. Frequently it was found impossible to pull up new wire from the reels because of friction in the

*Digest of "Open-Hearth Immersion Pyrometers", by A. Goodall, *Journal* of the Iron and Steel Institue, Vol. 180, July 1955, p. 247-254.



Niagara Falls, N.Y., Plant





Morganton, N. C., Plant

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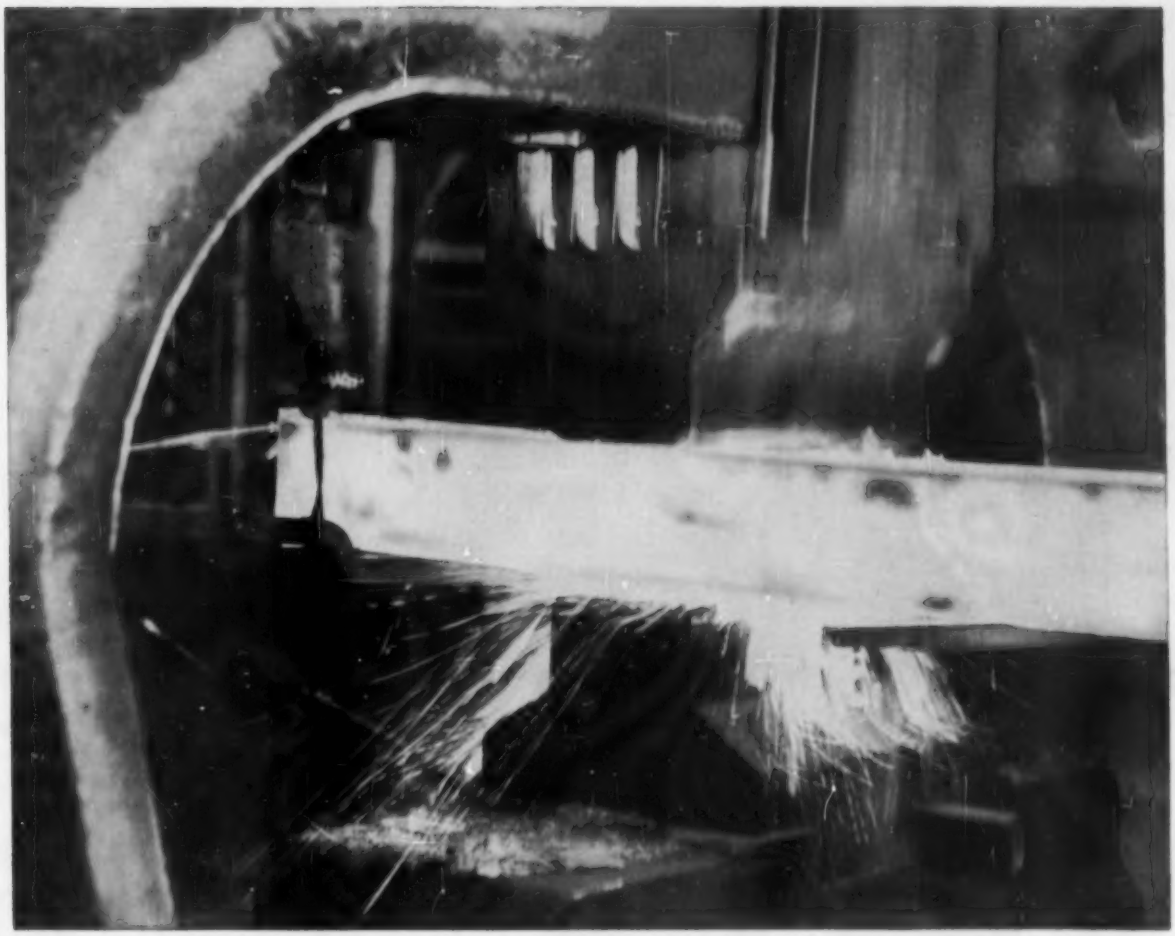
Pyrometers . . .

reels, dragging in the slack lengths of sleeving, or snagging in the glass tube bends.

In a later model, reels of spare wire were discarded in favor of an asbestos cement magazine unit placed in the right-angle bend near the hot junction. Wires in the body thus became stationary and abrasion of the sleeve insulation was avoided. However, the glass fiber sleeving tended to break down and become hygroscopic after being subjected to temperature of about 570° F. By changing to oval twin-bore clay insulators retained in register in an oval steel carrier tube, completely free wire passage was assured from the reserve wire supply which was moved back to a reel box at the handle end.

Next step was to try outer sleeves of carbon block instead of the cement paste layer, but there was a limitation on the thickness of such insulation in order to keep over-all weight in the neighborhood of 40 lb. A further disadvantage of the carbon-covered tubes was that, after an immersion, a thermocouple could not be picked up, even with leather gloves, for about 20 min. This was too long a wait in a seven-furnace shop. Hence a switch was made back to the cement paste coating, in combination with the twin-bore wire insulators. The latter were tried in both thin-wall and thick-wall mullite as well as in cement asbestos which gave the best performance. However, since the asbestos was available only in sheet form the cost of machining the oval tubes proved prohibitive.

A later design revision was made in the end pipe, consisting essentially of pinning the carbon block carrying the hot junction wires to the end pipe. When metal penetration occurs, the cotter pin is withdrawn and the block may be salvaged. Without unthreading it from the pyrometer, the end pipe is then sawed off at such a position as to clear metal penertation. The wire is recovered by acid treatment. The element wires having been cleared, the old end pipe is removed, the wires are drawn up to the correct height and a new end pipe is fitted. This procedure reduced the amount of wire removed from the pyrometer



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Here's another important advantage of vacuum-melted alloys — *substantially higher impact resistance* . . . over 25 times greater, for example, in one grade of stainless steel.

Tensile strength, stress rupture strength at elevated temperatures, fatigue life, ductility, uniformity, and fabricating characteristics are improved, too, by vacuum-melting.

Here's why . . . *Vacuum-melting literally sucks gaseous impurities from the molten metal . . . removes inclusions and gases that limit the performance of conventional air-melted alloys. That means purer metals that are stronger, tougher . . . closer to their theoretical limits of properties.*

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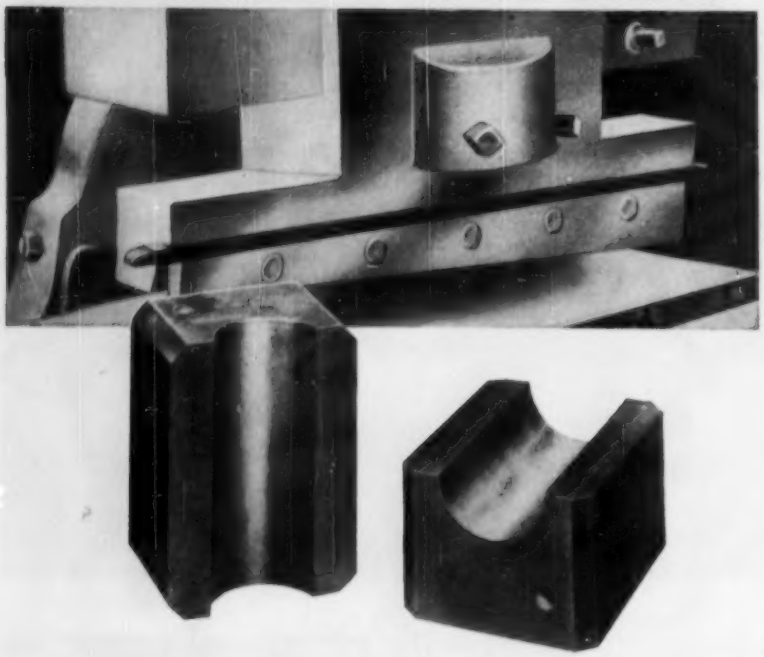

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Pyrometers . . .

following metal penetration by sheath breakage.

It has been concluded that less wear and tear on the element wires and a greater wire recovery are realized by placing the wire supply on reels at the handle end. However, the full advantages of this method are gained only when a strong, permanent electrical insulation has been perfected. A. H. ALLEN

Zirconium . . .

(Starts on p. 81)

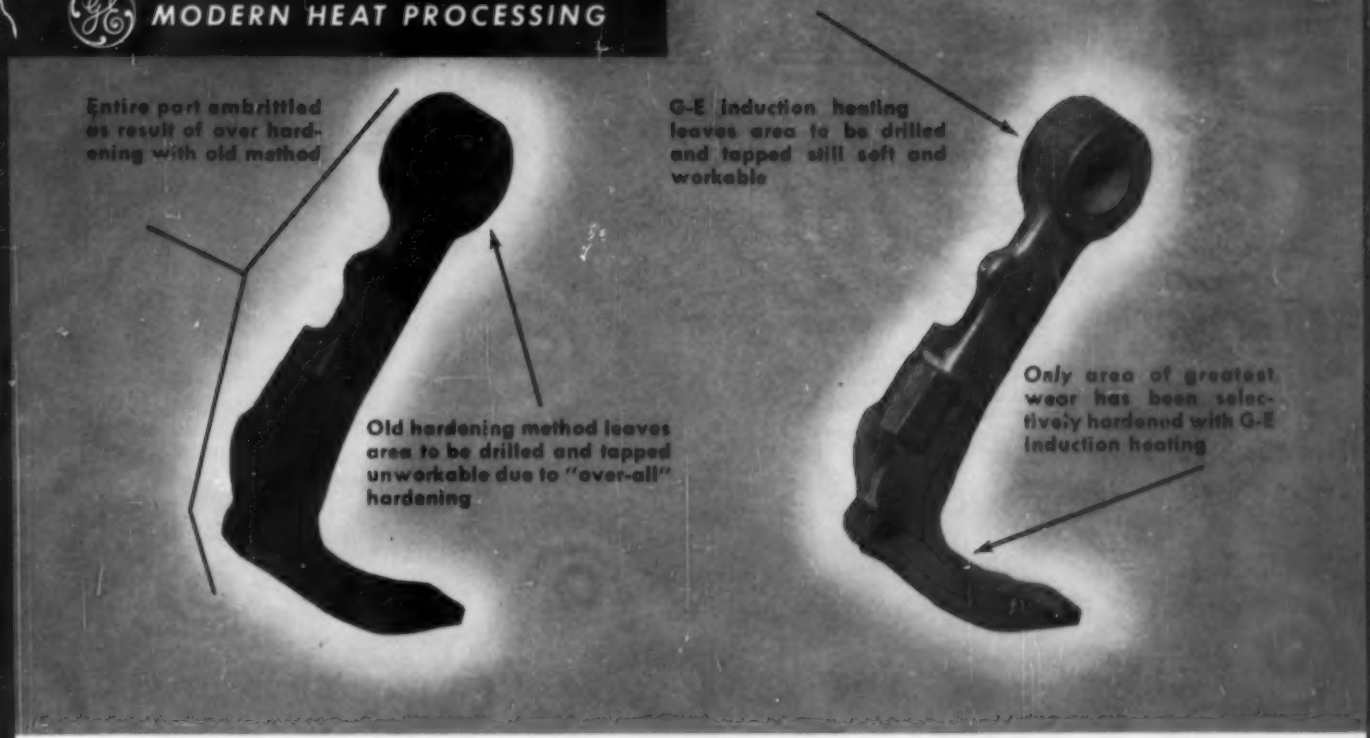
extruded rods were vacuum annealed at 750° C. (1380° F.) for 30 min. With −80-mesh powder the Rockwell hardness was B-83 to 85, whereas +80-mesh powder produced somewhat softer rods, B-76 to 80. These same materials when arc melted were B-94 and 89 respectively.

This zirconium can also be hot rolled at 775° C. (1425° F.) into strong, dense sheets. To do this, cold pressed compacts made from −80-mesh powder were jacketed in mild steel containers and hot rolled a total of 80% reduction, resulting in full-density sheets. After a 1-hr. vacuum anneal at 750° C., the sheet showed a hardness of B-88 and had a transverse rupture strength of 200,000 psi.

Conclusions — Zirconium is a metal of pertinent interest to designers of nuclear reactors. Its special nuclear characteristics guarantee this interest for years to come. The technology and art of fabricating solid shapes have been worked out. Powder metallurgy constitutes a significant part of this development. Solid zirconium bodies can be fabricated by powder techniques to possess physical and mechanical properties approaching those obtained on arc melted and worked metal. High-quality parts can be produced using very practical temperatures, times and pressures.

Since the metal is highly reactive with most gases at fairly low temperatures, special techniques had to be developed to handle the powders and compacts. The knowledge gained from this work will be of considerable value to investigators dealing with other reactive metals. The advantage of pressing and sin-

MODERN HEAT PROCESSING


Entire part embrittled as result of over hardening with old method
Old hardening method leaves area to be drilled and tapped unworkable due to "over-all" hardening
G-E induction heating leaves area to be drilled and tapped still soft and workable
Only area of greatest wear has been selectively hardened with G-E induction heating

PROBLEM:

Chill-cast rejects at Draper Corporation due to (1) Embrittlement (2) Over-all hardening

SOLUTION:

G-E Induction Heater Cuts Rejects 95% By Pinpoint Hardening Cast-iron Parts

The East Spartanburg, S. C. division of Draper Corporation was having difficulty controlling the hardening of cast-iron parts. Their old chill-cast hardening method forced them to reject many of the parts, which were overhardened and brittle. In addition, they had no way of controlling the size of the area to be hardened. This made drilling and tapping operations difficult—and frequently impossible.

SINCE INSTALLING A 20-KW G-E induction heater in their production line, they are able to cast the parts, drill and tap them while the cast iron is still soft, and then selectively harden only the area of greatest wear. This "pinpoint" hardening reduces the heated area of the parts by 70–90%. As a result, rejects have been cut 95%, costs are reduced, and the Draper Corporation is producing a product of uniform high quality.

THE COMPLETE SATISFACTION of Draper Corporation with their General Electric induction heating equipment was expressed by Mr. Fred Burgess, Plant Engineer: "Our G-E induction heater has been in operation for over five years. During that time we have greatly reduced manufacturing costs because of our decreased scrap losses and increased production. Maintenance of the heater hasn't been any problem, either. We just couldn't ask for any better service than we've had from our G-E equipment."

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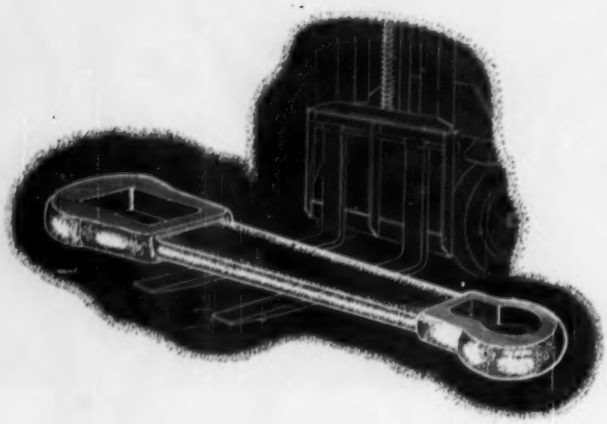

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***Patents applied for**

****SparTan Engineering West Coast Licensee**

Zirconium . . .

tering zirconium hydride has been clearly brought out – a technique which ought to be of value for other metals, such as titanium and vanadium, which readily form a hydride.

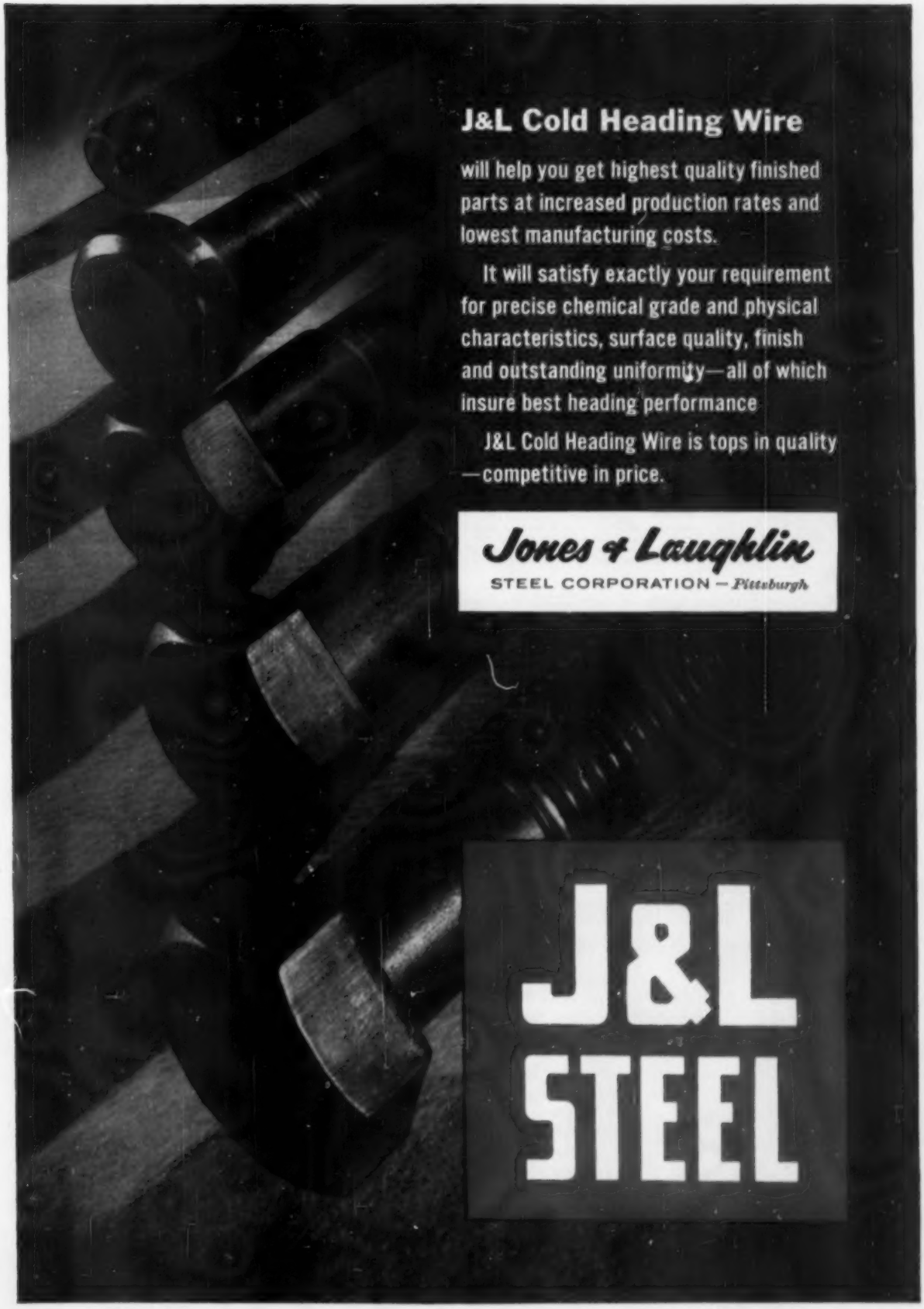
The powder metallurgy of zirconium and the evaluation of the products are not so highly developed as for beryllium. This is largely due to the earlier interest in beryllium. More work is needed on the various methods of preparing zirconium powder, the techniques of consolidation, and a detailed evaluation of the physical, mechanical and chemical properties of the finished parts. No work has been done on the preparation of zirconium alloys by powder techniques, and in view of the beneficial effects of small alloying additions to zirconium, this, too, offers a fertile field for study.

Variables in Seam Welding Low-Carbon Steel*

FURTHER light on basic procedures for the fabrication of pressure-tight lap seam welded joints in low-carbon sheet steel has been shed by recent research studies at the University of Texas. The work covered resistance seam welding of hot rolled, pickled and oiled, rimmed S.A.E. 1010 steel, in three thicknesses – 0.031, 0.049 and 0.078 in., respectively – welded under varying conditions of current, time and electrode force, particularly at higher current values.

A series of "pillow" test specimens, ranging in size from 6 x 6 to 10 x 10 in., was made for each run. The test is hydrostatic in nature, with two sheets seam welded around the edges and then attached to pumping equipment by means of a small pipe nipple welded to one sheet. If the weld is pressure tight, failure usually will occur on an inside edge of the seam. Additional specimens for microstructure examination, radiographic tests and weld nugget properties were prepared in the form of strips 1 in. wide. *(Continued on p. 164)*

*Digest of "Seam Welding Low-Carbon Steel", by M. L. Begeman and Gene C. Walker, *Welding Journal*, Vol. 20, March 1955, p. 123.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STEEL

Figure 1 shows the microstructure of a steel after it has been quenched at 500° F. The same specimen is shown in Figure 2 after reheating for one hour at 800° F. An original automotive paint surface is shown in Figure 3; Figure 4 is the same surface after the binder has broken down and free pigment particles have appeared, forming a whitish surface layer.

In producing its great line of cars "with the forward look," the Chrysler Corporation uses the RCA Electron Microscope to inspect many of the materials. These studies cover steel, paint finishes, rubber parts, metal powders, brake linings, and the extremely fine colloidal particles used for reinforcing fillers in plastics and rubber.

The investigations, which are headed by Dr. D. M. Teague of the Chrysler Physical-Chemical Research Department, also have been broadened to include foundry smoke and the effect of wear upon metallic parts.

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More and more the use of the RCA Electron Microscope is becoming mandatory throughout industry for the high magnification and resolution it affords. Find out how the Electron Microscope can help you . . . to determine the structure of materials, control quality, cut costs, save time, accelerate development work. Installation supervision is supplied and contract service by the RCA Service Company is available, if desired. For complete information, write to Dept. Z-72, Building 15-1, Radio Corporation of America, Camden, N. J. In Canada: RCA VICTOR Company Ltd., Montreal.

Seam Welding . . .

Welding equipment was a 250-kva. friction-driven circular seam welder with separate electronic control using two ignitron power tubes. Electrodes, of copper alloy, were each 10 in. diameter, ½ in. thick, double beveled to provide a face width of ¼ in. for 0.031-in. steel, 5/16 in. for 0.049-in., and ⅜ in. for 0.078-in. sheets.

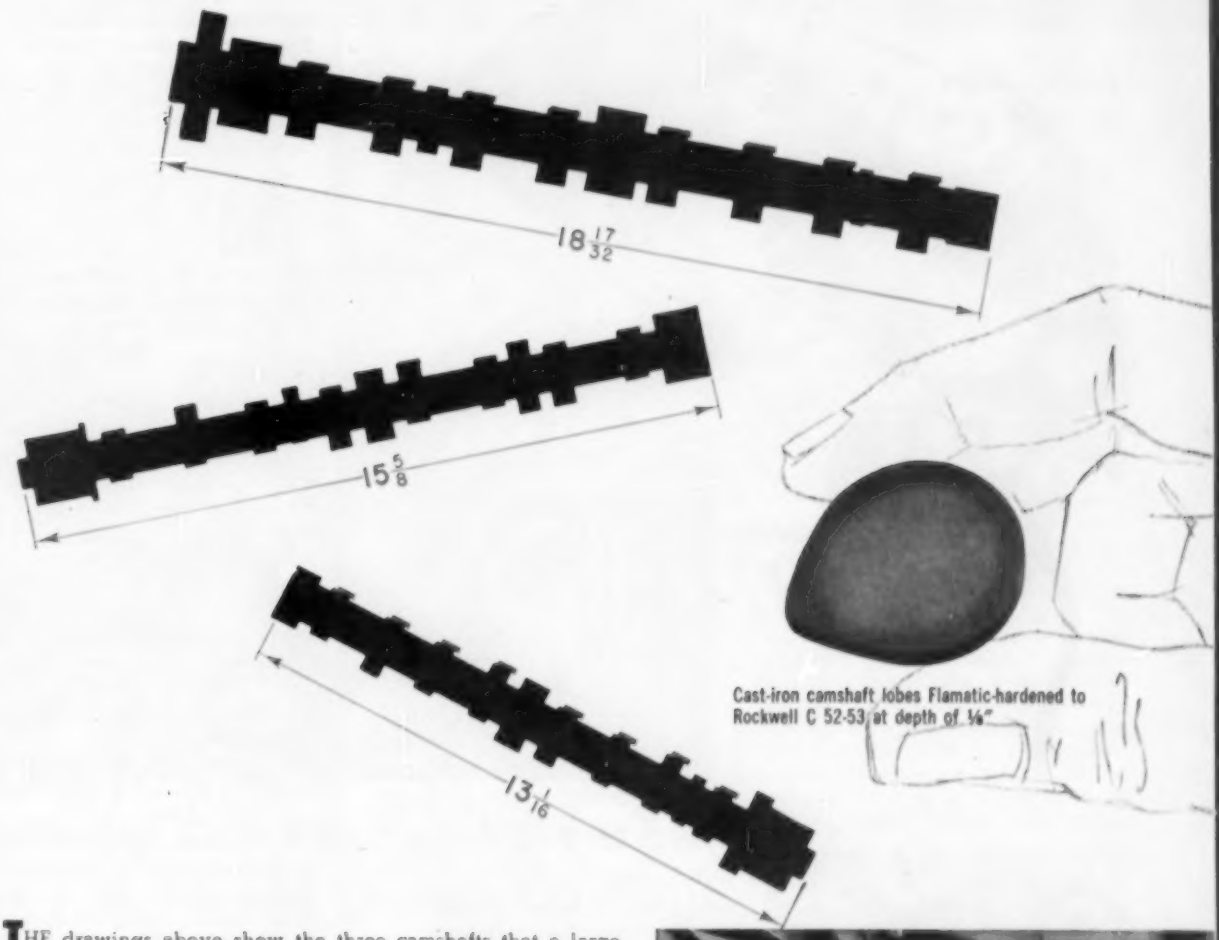
Instrumentation included means for measuring electrode force, welding speed and welding current. The latter is the most difficult to gage because of the use of partial current wave forms and interrupted pulses. For work with essentially full-wave continuous current and with interrupted current of at least two cycles on-time, a pointer-stop ammeter and current transformer were employed. For interrupted current of one cycle on-time and with partial wave continuous currents, the pointer-stop ammeter was checked by an air toroid around a current-carrying arm of the welder with suitable integrating circuit and oscillograph.

The five variables to be considered in seam welding are: current magnitude, heating time, cooling time, degree of force between electrodes, and welding speed. Good welds call for the proper control or setting of each variable; however, tests disclose that for each factor the optimum condition is not fixed but rather covers a fairly wide range. Choosing the best position in the range is governed by the other variables and in some instances may be a compromise with the other factors to obtain desired weld qualities.

Currents for seam welding must be slightly higher than for spot welding because of the shunting effect of adjacent overlapping spots. Current is increased as welding speed or thickness of material is increased. Limiting factors in stepping up welding speeds include electrode pick-up, porosity due to weld cooling without proper pressure, and welds with insufficient nugget overlap.

Criteria for satisfactory seam welds are basically three: minimum porosity; enough nugget overlap to insure tight welds, and reasonable allowance for deviations in welding variables to effect uniform results. Established standards specify nugget overlap of 15 to 20% and weld

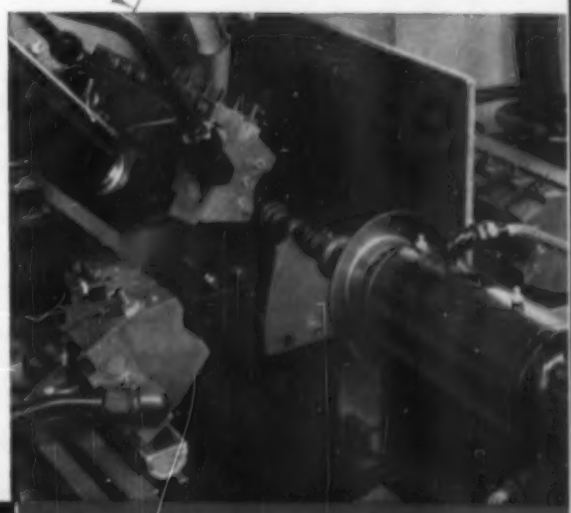
1 flamatic hardens 3 different camshafts



Cast-iron camshaft lobes Flamatic-hardened to Rockwell C 52-53 at depth of 1/16"

THE drawings above show the three camshafts that a large automotive manufacturer asked Flamatic to harden selectively on a single machine. The close-up at the right shows how Flamatic flame hardening solved the problem through simple, ingenious tooling. The machine achieves high production, yet set-up changes take less than 15 minutes. The operator positions the water-cooled shield, sets the selector-switch for the proper flame head, and adjusts the work-holding fixture. The cycle is then automatic except for loading.

This is another case out of hundreds showing how Flamatic selective hardening provides rapid heating and precise temperature control which results in high production and uniform performance over a wide range of parts. Write for Catalog No. M-1861, or send us part prints for analysis.



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Seam Welding . . .

penetration averaging 45 to 50% of the original sheet thickness.

Heat produced in seam welding by the passage of current has three sources. First, the contacts between electrodes and work have a certain resistance and thus produce heat. At these points heat is held to a minimum by the use of copper alloy electrodes; it is dissipated by rapid cooling of electrodes and the weld area, usually by external flood cooling with water. Second, the column resistivity of the metal being welded generates heat. Near the interfaces of the pieces being welded it contributes to the welding process, while the heat that is generated near the outside is carried away by the cooling water.

Third source of heat is the resistance of the pieces being welded at their interface. This heating, plus that from the internal resisfance of the metal, melts the metal in a localized region, producing fusion at the interface. When current is high enough to cause fusion, nuggets of weld metal are formed. With interrupted current, these nuggets may be varied from individual welds, as in the roll-spot welding process, to a series of overlapping welds, as in seam welding.

As welding current is increased, the failure pressure in the previously mentioned pillow specimens increases to some maximum value, dependent upon the thickness of the material and size of the test specimen. Current values in excess of those giving full strength serve to increase penetration and overlap but add nothing to strength of the welds. The minimum current which will produce full-strength welds gives nugget penetration of about 30%.

Increasing electrode force or pressure gives greater nugget penetration, up to a certain point where penetration starts to decrease as the result of widening out of nuggets. Good welds are made on 0.078-in. sheets with electrode force of 1500 lb.; on 0.049-in. material, 1050 lb.; and on 0.031-in., 700 lb.

With respect to weld time, it was determined that welds of good quality were produced in 0.078-in. stock with a heat time of 6 cycles and a cool time of 5 cycles; in 0.049-in. material with a heat time of 4 and

Tool Steel Topics

BETHLEHEM STEEL

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Distributor: Bethlehem Steel Export Corporation

Notching Die Made of Bearcat Gives 7 Times Greater Output

An interesting item being manufactured in the southeastern part of the country is a windshield garnish molding for a popular make of automobile. The molding is produced from cold-rolled steel, 0.020 in. thick. It is formed by a notching die, hardened to Rockwell C 56-58.

With the grades of shock-resisting tool steel formerly used for the die, a maximum of 1400 pieces was produced before breakage occurred. Because of the severity of the application, this was considered good production even though it necessitated a change of die about five times daily.

After studying the operation, we suggested a change to Bearcat tool steel. "Bearcat is a super shock-resisting grade," we said. "We're sure it will last longer in a tough job like this, and so save you money. Why don't you give it a try?"

So Bearcat was put to work. The dies made of Bearcat have been giving a good account of themselves by producing up to 10,000 pieces before being replaced. That's seven times the output obtained from the dies before changing to Bearcat.

Surprising? Not at all. Bearcat is continually chalking up new performance records in a variety of interesting applications. Bearcat is a superior, general-purpose grade of air-hardening tool steel. It has exceptional resistance to shock, and is also well suited for uses where hot-work properties and easy machining are essential. Bearcat can be used in a wide range of applications such as punches, master hobs, engraving dies, and short-run dies used in cold-forming, blanking and bending.

The best way to determine how good a job Bearcat can do is to put it to work on some difficult job in your shop. You can order Bearcat through your local Bethlehem tool-steel distributor. We also carry it in stock in our mill depot.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

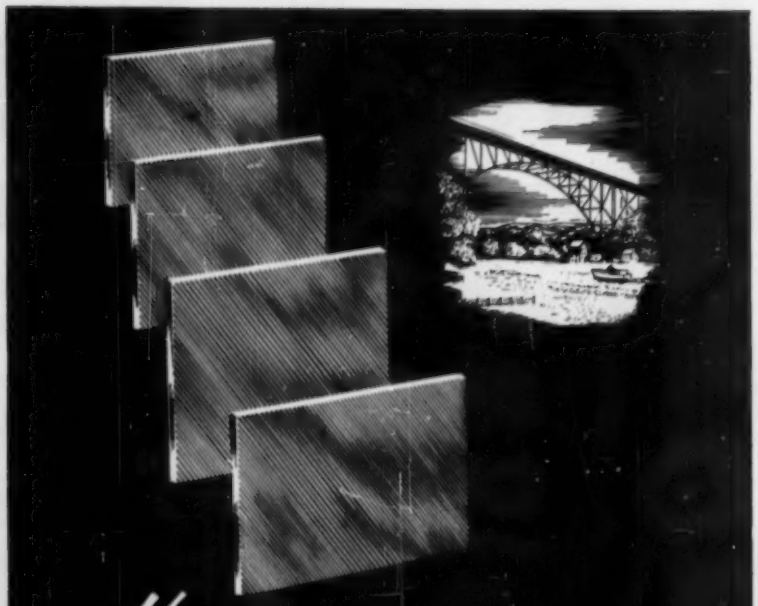
Retemper Tools After Grinding

No matter how carefully performed, grinding operations on hardened tools always generate residual stresses in the tools. But as tools already contain residual stresses after they are quenched, any additional stresses are likely to cause trouble. Now, if the combined stresses are sufficiently high, cracking may occur during grinding, which makes it easy to locate the source of the trouble. But if the combined residual stresses are just below the ultimate strength of the steel, cracks will not appear for the time being. Instead, the tools are apt to crack subsequently, at the application of normal stresses set up either in handling, or in using the tools.

To avoid this difficulty, we recommend reducing the stresses to a safe level by retempering the tools immediately after grinding, using a temperature which is slightly lower than the original tempering temperature. With many toolmakers, retempering after grinding is routine procedure, a form of insurance, more or less, against running into trouble.

BLANKING DIE FOR HANDBAG HANDLES

This blanking die, used by Westberg Tool and Manufacturing Company, Bridgeport, Conn., for the manufacture of handbag handles, has BTR (Bethlehem Tool Room) tool steel in both the die and the punch. BTR is our long-wearing, general-purpose, manganese-chromium-tungsten grade of oil-hardening tool steel.



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Seam Welding . . .

cool time of 3 cycles; and in 0.031-in. material a heat time of 3 and cool time of 2 cycles.

Welding speeds up to 200 in. per min. were possible with the seam welder used in these tests. The principal difficulty encountered at higher speeds was severe burning of the metal with resultant electrode pick-up. In welding with continuous current, speeds of 200 in. per min. were readily achieved on 0.031 and 0.049-in. steel, but 100 in. per min. was found to be the maximum for satisfactory welds in 0.078-in. stock.

A. H. ALLEN

Inert-Gas Tungsten-Arc Welding of Pipe*

INERT-GAS tungsten-arc welding was first used on thin-walled piping and tubing in the chemical industry a few years after the end of the second world war. Only now is this process becoming accepted for the so-called root-pass welding of heavy piping.

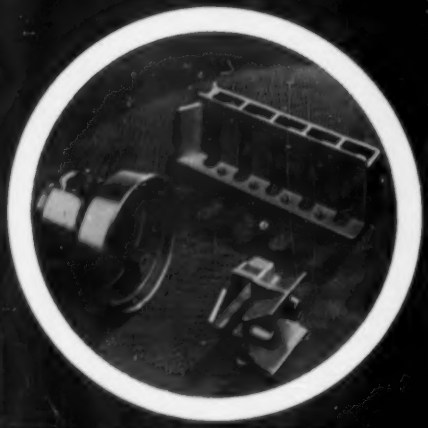
On pipe and tube joints of wall thickness up to ¾ in. the entire weld is made by the inert-gas tungsten-arc process. On piping and tubing of heavier wall thickness usually only the root pass is made by this process and the rest of the weld is made by manual metal-arc welding or by automatic welding.

The first applications were in stainless steel pipe and tube materials. In recent years increasing use has been made of inert-gas tungsten-arc welding of low-alloy and carbon steel tubing and piping.

Various joint designs have been recommended. The "U" and the special "V" bevel preparation with the "flat-land" are more costly to machine than the straight "V" bevel. However, the "U" and "flat-land" bevels allow better manipulation of the tungsten electrode and faster electrode travel. They reduce susceptibility to cracking in the root de-

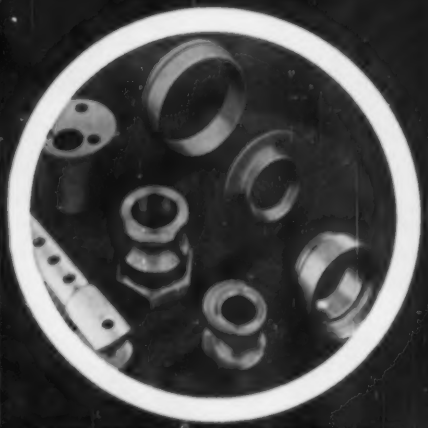
(Continued on p. 170)

*Digest of "Engineering Aspects of Inert-Gas Tungsten-Arc Welding of Piping", by H. Thielsch and C. S. Pulliam, American Welding Society National Spring Meeting, Kansas City, Mo., June 7 to 10, 1955.



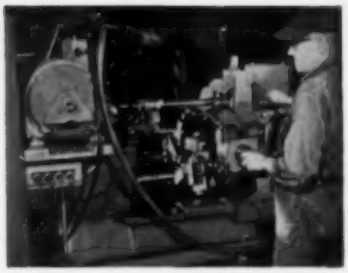
Titan brass pressure die castings

Titan brass and bronze forgings



Titan brass and aluminum hand screw machine parts

One of Titan's modern automatic chucking machines for preparing brass and aluminum forgings to customer specifications. Titan performs all types of machining operations.



Accurately machining a Titan forging on a turret lathe. Titan fabricating operations cut customers' assembly costs.

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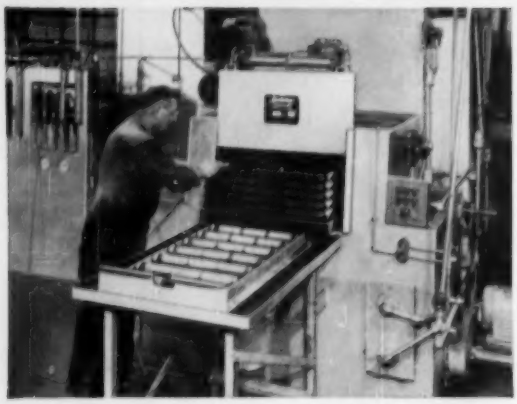

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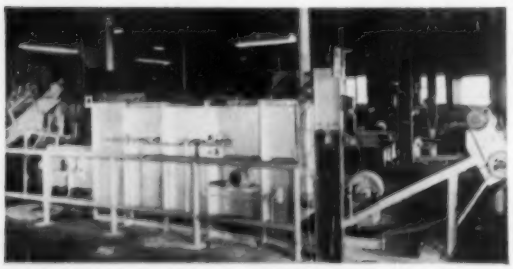

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	Tungsten Carbide (WC)	Titanium Carbide (TiC)	Tungsten-Titanium Carbide ($WTiC_2$)	Tantalum Carbide (TaC) with less than 5% CbC
Tungsten (W)	92.50% (min)		67.00-71.00%	
Titanium (Ti)		79.80-80.20%	18.00-21.00%	
Tantalum (Ta)				93.45-93.65%*
Carbon (C)	6.05-6.15%	19.20-19.60%	9.20-9.40%	6.35-6.55%
Columbium (Cb)				5.00% (max)
				*Including CbC
MAXIMUM IMPURITY CONTENT				
Free Carbon	0.05%	0.20%	0.05%	.....
Fe	0.15%	0.40%	0.10%	0.10%
Mo	0.10%	.....	0.30%	.....
Ni	.....	.....	0.20%	.....
Cb+Ta	0.50%	.....	0.50%	.....
Ti	0.20%	.....	.....	0.50%
Si	0.10%	0.10%	0.10%	.....
Mn	0.10%	0.10%	0.10%	.....
V	.....	0.10%	.....	.....
Zr	.....	.....	.....	0.20%
Sn	.....	.....	.....	0.10%
W	.....	0.20%	.....	0.30%
Cr	.....	0.10%	.....	.....
N_2	.....	0.30%	.....	.....

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Perhaps one or a combination of these characteristics is just what you need to get YOUR idea into production. We invite you to send for additional information about Kennametal. Write to KENNAMETAL INC., Latrobe, Pennsylvania, and ask for a copy of Booklet B-111. 7295

*Kennametal is the registered trademark of a series of hard carbide alloys of tungsten, tungsten-titanium and tantalum.

RANGE OF PHYSICAL PROPERTIES OF VARIOUS GRADES	
Specific Gravity gms/cc	11.90-15.15
Thermal Conductivity (cal/°C/cm/sec)	.068-.207
Electrical Conductivity (% of Copper Standard)	4.3-10.0
Coeff. Thermal Expansion ($\times 10^{-6}$/°F up to 1200°F)	2.5-4.0
($\times 10^{-6}$/°C up to 650°C)	4.5-7.2
Magnetic Permeability (μ Induction)	1.5-3.0
RANGE OF MECHANICAL PROPERTIES OF VARIOUS GRADES	
Hardness (Rockwell A)	85-93
Hardness (Rockwell C)	67-82
Hardness (Knoop-K100)	1700-2100*
Transverse Rupture (psi)	175,000-385,000
Young's Modulus of Elasticity (psi)	61,600,000-94,300,000
Compressive Strength (psi)	518,000-800,000
Torsional Strength (Shearing Stress psi)	100,000-186,000
Tensile Strength (psi)	To 150,000
*Partial Range	

INDUSTRY AND KENNAMETAL ...Partners in Progress

Welded Pipe . . .

posit and root penetration is more uniform. Greater skill also is required for welding in the conventional "V" bevel than for the other two types of groove preparation.

Experience in laboratory and shop fabrication has shown that the initial enthusiasm for inert-gas tungsten-arc root-pass welding was somewhat premature. Sections removed from commercially made pipe welds have contained fine root cracks which have sometimes been further extended during service. These cracks were not detected by conventional radiographic inspection and, consequently, were not removed prior to service.

The best insurance against fine root cracks and for complete root penetration is still the use of thoroughly trained and experienced welders and rigid inspection techniques. The task of welders and inspectors can be eased by use of filler wire, inert-gas backing or purging, controlled tacking procedure and consumable insert rings.

Filler wire is used for alloy steels susceptible to crater cracking, such as Type 347 stainless. Tack welds should be fused through the full thickness of the land and the electrode should be manipulated slowly onto the side of the groove before the arc is broken.

Purging the underside of the joint with inert gas is particularly important on thin-wall tubing to avoid the rough "cauliflower-type" formation. Using a pressure of about ¼ oz. per sq. in. also improves the internal bead contour.

Backing rings to provide solid metal back-up against which the root pass is deposited are used in power piping where a smooth inside surface is not essential. Consumable insert rings are fused, and mix with the metal as the weld progresses. They help control the weld composition in the root pass and improve the inside contour of the weld. They also permit greater tolerance for misalignment. A table of permissible offset and gap tolerances based on the ability of the average shop welder to obtain consistently acceptable welds shows that the fit-up must be closest for a "tight butt". When filler wire is used the tolerance is about twice that required without it. With

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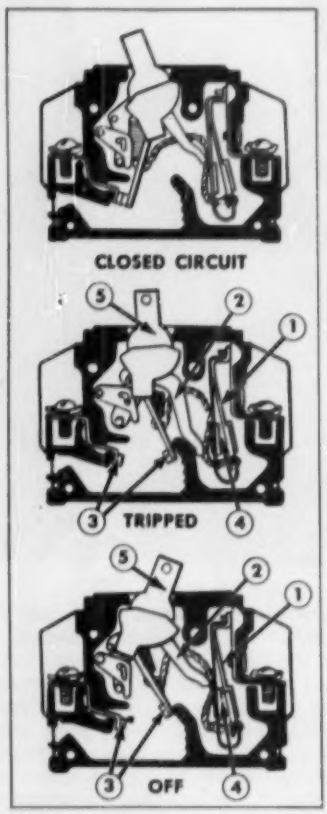
MAHON

How **CHACE THERMOSTATIC BIMETAL** Actuates the Westinghouse AB CIRCUIT BREAKER

Product of Westinghouse Electric Corp., Beaver, Pa.



Westinghouse AB Circuit Breakers are made in a wide range of capacities and types to provide foolproof protection against electrical current faults in residential, commercial or industrial wiring systems. Westinghouse AB Circuit Breakers employ a thermal-magnetic action for *sure* response to gradual or sudden overloads and short circuit faults.

HOW IT WORKS

A Chace Thermostatic Bimetal element (1) responds to temporary overloads by deflecting in a direction away from the spring loaded latching arm (2) causing the contact rocker to break the circuit at contacts (3) in response to the same spring tension. Under conditions of sudden, high overload, the magnetic trip element (4) trips the latching arm in the same manner. A simple flip of the reset handle (5) again closes the circuit after the fault has been cleared from the line.

Chace Thermostatic Bimetal is available in 29 different types, in coil, strip, or in complete elements fabricated to your specifications. To aid the product designer of thermally responsive devices, we offer a free 36-page booklet, "Successful Applications of Chace Thermostatic Bimetal." *Write today for your copy.*

IT BENDS WITH THE HEAT

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Thermostatic Bimetal
1626 BEARD AVE., DETROIT 9, MICH.

Welded Pipe . . .

consumable insert rings a good weld can be produced with three times the offset of a joint made without filler rod or insert.

Radiographic inspection of the root pass before additional layers of metal are deposited is recommended, although preheating practice often prohibits this. The disappearance of root pass cracks with weld metal build-up is illustrated by a series of radiographs. A bad crack shown by the X-ray of the root pass is barely visible when the weld is built up to ¼ in. thick and cannot be seen in radiographs taken when the metal is over ⅜ in. thick. The final radiograph at full thickness, 1⅜ in., shows a "perfect" weld. Twenty-four illustrations of welds, sections and radiographs were used to show the effects of good and bad practice.

DAN WHITE

Cause of Grain Size Variation in Castings*

IN THIS study the authors tried to establish, for a cast iron of given composition, a relation between the grain size and the dimensions of castings of simple geometrical shapes cast at different temperatures. The iron analyzed 3.40% total carbon, 2.70% silicon, 0.55% manganese, 0.05% sulphur, and 0.40% phosphorus. Grain size was estimated by intercept method – number cut by a line 1 cm. long. A summary of the relative influence of the factors studied is as follows:

1. *Dimension of Castings* – Grain size decreases as the dimensions decrease. Grain size variation in a casting increases as the thickness increases in relatively thin castings (0.10 to 0.50 in. thick), attains a maximum in castings of medium thickness (1.0 to 2.0 in.) and decreases again in very thick castings (4 to 8 in.).

2. *Casting Temperatu* Decrease in the casting temperature generally results in a finer grain size. This is particularly noticeable at the surface, and less pronounced in the center. The variation in grain size

*Digest of "Grain Size in Cast Iron", by M. Ferry and J. C. Margerie, *Fonderie*, Vol. 108, January 1955, p. 4299.

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Competitive Oil B	729	39.0
Competitive Oil C	1024	41.0
QUENCHOL 521	1369	54.5

*Based on a recognized formula for determining relative cooling power value. Measured as the square of the current (I^2max.) as recorded by Quenchol Demonstrator.

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Grain Size . . .

in a given casting is thus greater at low casting temperatures than at high casting temperatures.

3. *Shape of Castings* – The author presents three graphs showing how the number of grains at the surface and in the center varies with the ratio, volume to area, for pouring temperatures of 2730, 2550 and 2375° F. The number of grains at the surface varies with the shape, but this variation is much less important in the center. It would then seem that the number of grains in the center of a casting depends primarily upon the ratio between volume and surface area. Since the lower part of the three curves is practically linear, where the volume-area ratio is greater than 3, the number of grains times this ratio is a constant. Since the total solidification time for castings of a given shape varies as the square of this ratio between volume and area, the number of grains in the center of a casting is inversely proportional to the square root of the total solidification time.

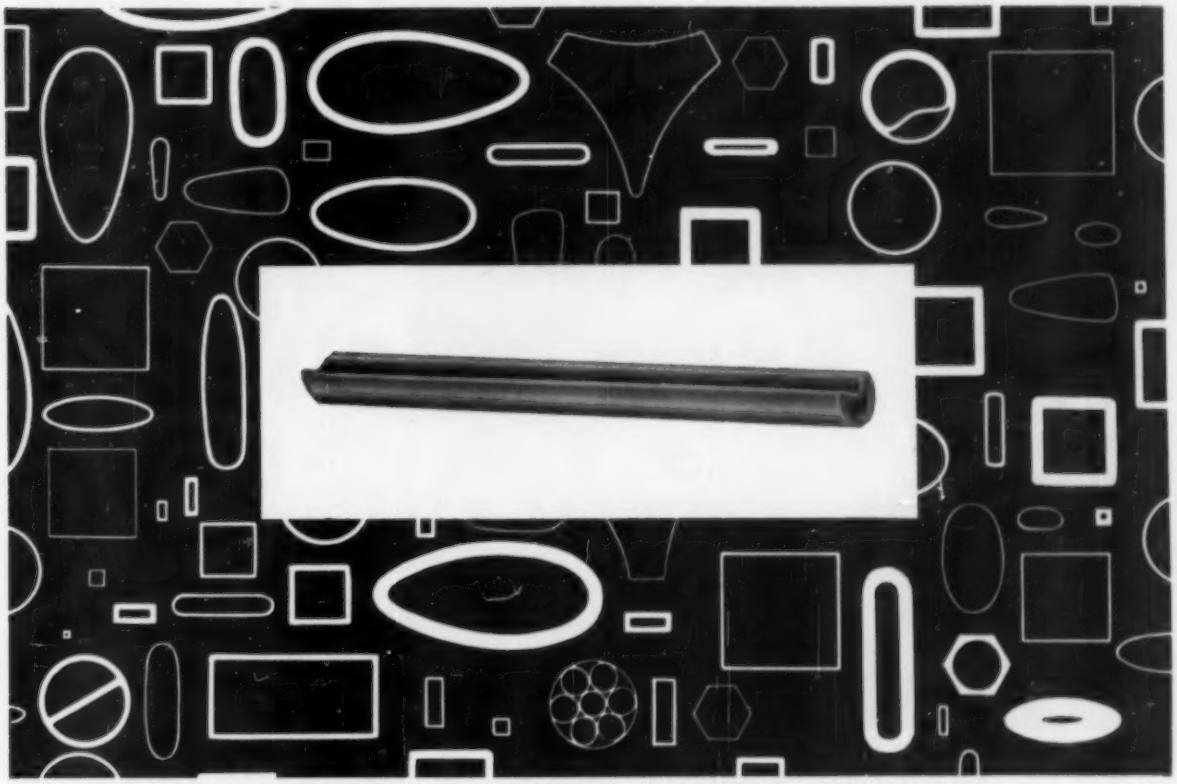
Cooling Conditions – From cooling curves plotted by the thermocouples inserted in mold cavities, no relation could be found between the number of grains and either the cooling rate of the liquid metal or the cooling rate just before the eutectic temperature is attained. The number of grains, in fact, can be related only to the temperature and the length of the eutectic arrest.

Experiments on 4-in. spheres indicate that the average cooling rates in the center are practically independent of the three casting temperatures used.

It then seems that the only factors relating cooling conditions and grain size are undercooling, and the length of the eutectic arrest. The degree of undercooling could not be measured, but the authors present an equation expressing the grain size in terms of the length of the eutectic arrest. They show that $tn^2 =$ a constant, in which "t" is the length of the eutectic arrest.

Shearing Strength – Specimens taken from round bars 0.6 to 2.0 in. in diameter show that the shearing strength increases as the grain size decreases.

Solidification Mechanism – Depending on the casting thickness and



A few of the shapes available from SUPERIOR in standard specifications and tolerances or to your own design. The tube in the foreground is a gun drill shank made from 4130 alloy steel.

Save time and money on special shaped tubing

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The gun drill shank shown above and on the right is a good example of SUPERIOR's ability to supply unusual shapes. This newly rediscovered method of producing close-tolerance high-finish holes demands straight, rigid, accurate shanks with a 110° V-groove. SUPERIOR can produce such a shape—and others—in a fraction of the time and cost it would take a customer to form his own.

If you're having difficulty getting the kind of tubing you want, SUPERIOR can undoubtedly help you. Write for your free copy of Bulletin 40—*A Guide to the Selection and Application of Superior Tubing*. SUPERIOR TUBE COMPANY, 2008 Germantown Ave., Norristown, Pa. *On the West Coast:* Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif.

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MANUFACTURERS OF BARREL FINISHING COMPOUNDS
TUMBLING BARRELS — MEDIA AND AUXILIARY EQUIPMENT

Grain Size . . .

the pouring temperature there are three different mechanisms of solidification:

1. In very thin castings convection currents are practicaly negligible and the temperature gradients in the liquid metal are large. The whole casting solidifies very quickly at a practically constant rate; the number of grains is large and almost uniform through the casting.

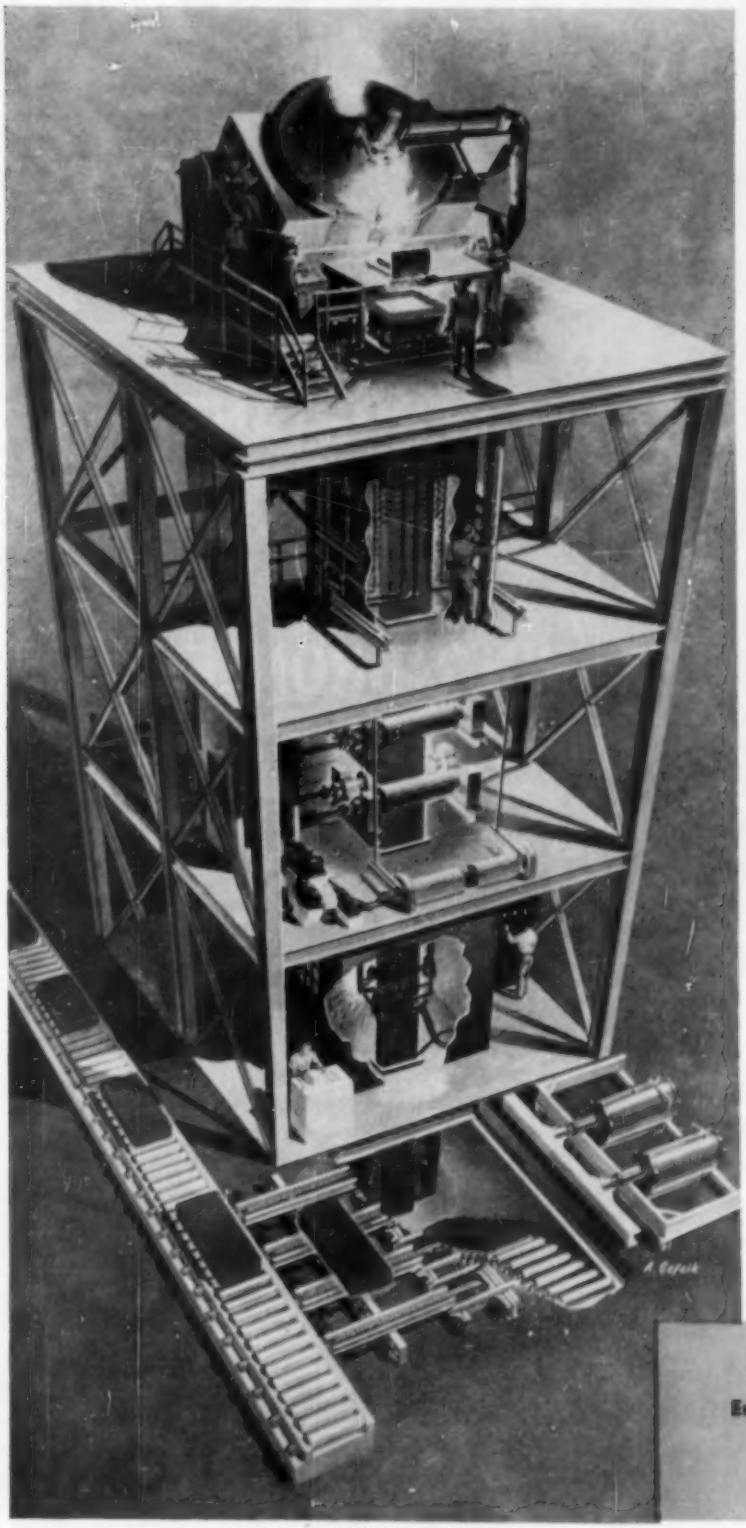
2. In very thick castings convection is very important and the metal that is in contact with the mold is constantly replaced by hotter metal before solidification starts. The inner face of the mold soon reaches the temperature of the liquid metal even if the casting temperature is low. When solidification starts the temperature gradients in the metal are small because the mold is very hot. Solidification is slow even at the surface. The grains are coarse and are practically uniform throughout the casting.

3. Before solidification starts in medium sized castings the sand is heated to a smaller extent than in (2) above, convection currents are less important, and temperature gradients are more pronounced in the early stages of solidification. If the V÷A ratio is low the metal in contact with the mold freezes quickly and the number of grains is high, and this is more pronounced at low casting temperatures. If the V÷A ratio is higher, temperature gradients in the liquid metal are smaller and convection currents are more important; the surface metal will freeze less quickly and the grain will be coarser. The higher the V÷A ratio, the more important the effect of casting temperature.

In chill-cast plates the point of maximum grain size is closer to the sand side of the plate at high casting temperatures than at low casting temperatures. The solidification front proceeding from the chill advances rapidly even at high casting temperatures. On the sand side of the plate the solidification front will proceed rapidly if there is little convection (that is, if the casting temperature is low); solidification will advance more slowly, however, if convection is more important (that is, if the casting temperature is higher).

ALFRED COUTURE

For the continuous casting of steel...



Koppers builds the first commercial-scale machine

The continuous-casting machine illustrated here is now in operation at Atlas Steels Ltd., Welland, Ontario, Canada. This is the first commercial-scale installation in North America that, in a continuous line, converts molten steel into solidified billets or slabs. It was designed and constructed by the Freyn Department of Koppers Engineering and Construction Division.

Atlas Steels' machine is presently producing slabs and billets in three sizes. With different molds, this machine also could produce any desired billet section. It is designed to cast 35-ton heats.

In theory, this new machine could cast a billet or slab of steel many miles in length; it is limited only by the supply of molten metal. In actual practice, acetylene torches automatically cut the molded steel into required lengths as it emerges from the machine.

Continuous casting is an *economical* short-cut in steelmaking. It eliminates the need for ingot-casting and stripping equipment, except the ladle crane. Soaking pits and blooming mills can be by-passed. Also, the Freyn-design continuous-casting process can yield 10 to 15 per cent more finished steel per heat than conventional pouring methods.

Your inquiry is invited concerning the continuous-casting operation . . . or any other metallurgical construction problems you may have. You incur no obligation.

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Sintering and Cold Rolling of Thorium*

This paper gives a good review of previous work on the powder metallurgy of thorium and then describes extensive experiments on the effect of compacting pressures on the metal powder, sintering temperatures, and sintering times upon the physical and mechanical properties of the sintered metal. Fabrication properties of the metal are also commented on.

Carefully purified thorium powder was used in this investigation. The main metallic impurities were: calcium, 300 parts per million; magnesium, 160 ppm.; iron, 47 ppm. and oxygen, less than 0.4%. Since oxygen content could not be determined on the powder, the latter figure is based on analysis of sintered metal. All of the powder used was screened through 200-mesh sieve.

Thorium metal is difficult to compress because of its tendency to stick to the metal die. Use of a lubricant contaminates the purified powder. Compacts $5 \times 5 \times 50$ mm. were prepared with special dies mounted in a tensile testing machine. Because of the tendency of the thorium powder to seize the steel dies it was necessary to dismantle the forming dies in order to remove the compacts without cracking or breaking them.

Both sintering and annealing were carried out in a horizontal platinum-wound furnace having a mullite tube, under a vacuum of 4×10^{-5} mm. of mercury at temperature because of the high affinity of thorium powder for oxygen. Compacts were supported on a grid of molybdenum wire held in a molybdenum boat, which could be moved in and out of the furnace, working through a Wilson seal.

The experimental work consisted mainly of determining the most favorable compacting pressure, sintering temperature and time that would yield the densest finished compacts. All of the thorium investigated for physical properties was treated by pressing at 50,000 psi. and then sintered for 2 hr. in the vacuum furnace at 2370° F. The density of this product was 11.0 to

*Digest of "The Sintering, Fabrication and Properties of Thorium", by M. D. Smith and R. W. K. Honeycombe, *Journal* of the Institute of Metals, Vol. 83, May 1955, p. 421-426.

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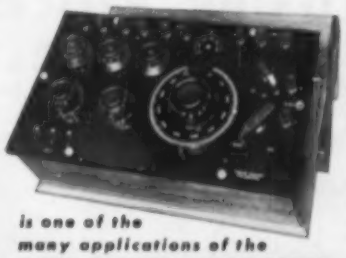

is one of the many applications of the
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- Exceptional convenience in reading and adjustment.
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This standard laboratory potentiometer is also well suited for meter calibration, for checking portable potentiometers, and for other critical measurements of D.C. potentials requiring exceptionally high accuracy.

Described in Bulletin 270

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- For null or deflection measurements

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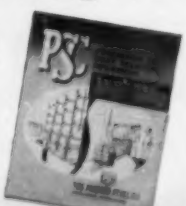

THE PRESSED STEEL CO • Wilkes-Barre, Pa.

PSC

Thorium . . .

11.1 g. per cc.; the density of metalic thorium is 11.7.

These compacts were very ductile, and they could be cold rolled with 50% reduction in thickness quite readily. When the cold rolled metal was then resintered for 2 hr. at 2370° F. the density increased to 11.60 to 11.65, close to the theoretical density of thorium.

All of the mechanical properties reported were determined on a resintered metal. These resintered specimens were very ductile and could be cold rolled with as much as 95% reduction without any sign of cracking. A peculiar characteristic of thorium was noted when attempts to cold draw the compacts were made. Here the tendency of thorium to seize the draw dies under high pressure was evident; in every instance the wires broke and the product had a rough, cracked surface. No satisfactory lubricant was found which would overcome this problem. The tensile strength of sintered thorium was 41,500 psi. Cold rolling with 13% reduction increased the strength to 50,000 psi. and 90% reduction to 87,500 psi.

Annealing of cold rolled thorium begins at about 930° F. and is complete at 1290° F. During annealing the grain size changes from about 140 to about 43 grains per sq. mm. after a 1-hr. annealing treatment at 1290° F.

Conclusion – It has been shown that thorium powder may be readily sintered and fabricated to produce metal of high density, with an oxide content between 1.5 and 2.0%.

The main impurity in sintered thorium is oxygen, present as a microscopic dispersion of thoria particles. The percentage of thoria present can be reliably determined by point-counting. Somewhat surprisingly, the oxide does not interfere with the metal's ductility and cold workability.

The good working characteristics of the metal are in accordance with the known properties of other face-centered cubic metals. Oxygen appears to have a more marked effect on metals with noncubic structures, such as titanium and zirconium. The earlier work on thorium has thus been substantiated, but it should be emphasized that the metal used in

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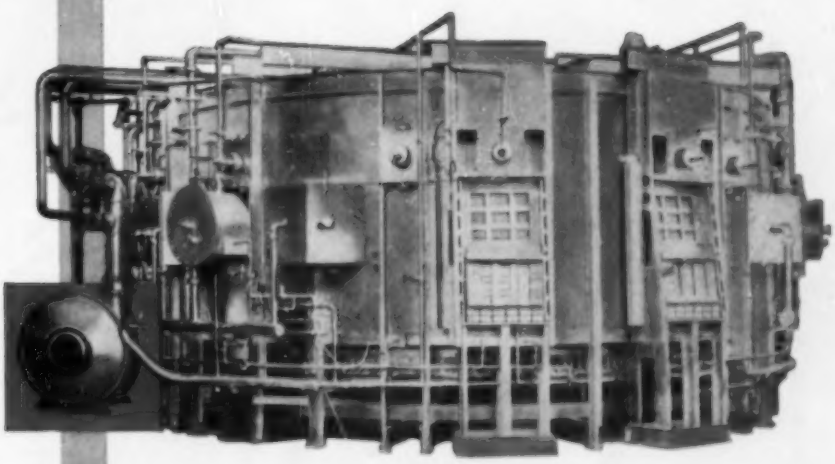

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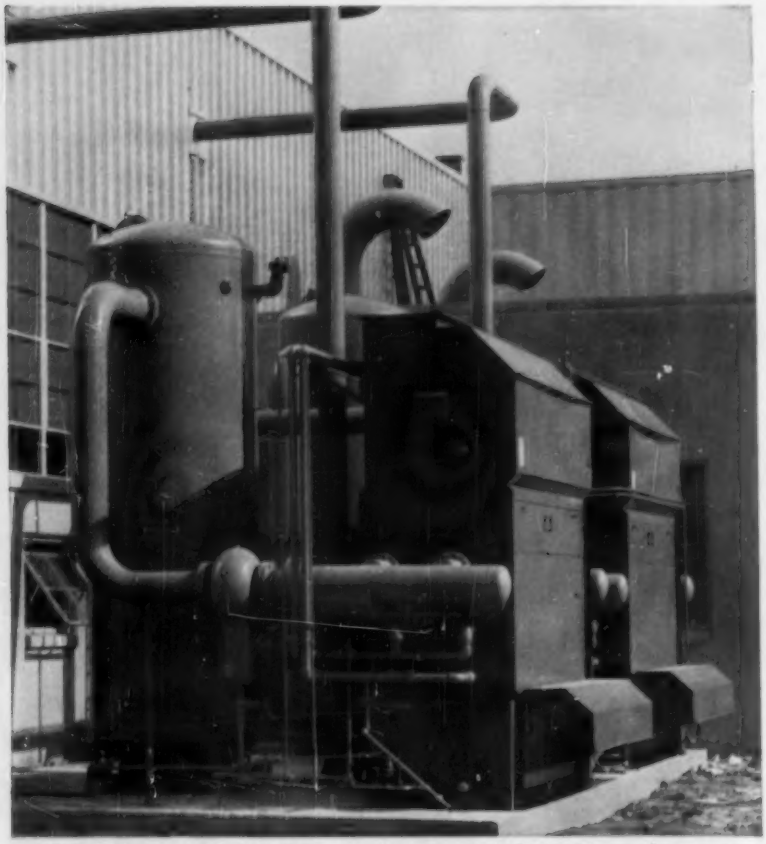

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Thorium . . .

the present investigation yielded even more satisfactory properties, presumably because of its higher purity.

Rolling is a feasible method of fabrication but other methods, such as wiredrawing, may present a problem in lubrication.

E. C. WRIGHT

Controlling Depth-of-Chill of Cast Iron*

So many factors, difficult to determine, govern whether cast iron will solidify hard (chilled) or soft (graphitized) that a chill test is always used to show what depth of chill is to be expected in castings from a given melt. The British Cast Iron Research Association has published a summary of several laboratory investigations of the the factors affecting chill-test results. The iron used contained 3.2% C, 0.9 Si, 0.35 Mn, 0.1 S and less than 0.1 P. The test specimens were 9 in. long, 6 × 1¾ in. at the top and 5 × 1¾ in. at the bottom, which was chilled. After solidification these specimens were broken so that the fracture extended from top to bottom through the center. Photographs of the fractures show the extent of the white chilled structure.

The first series of tests confirmed the well-known fact that depth of chill increases as melting temperature rises, even with constant pouring temperature. Superheating at 2570 to 2730° F. increased in chill depth still further. When the iron was heated to 2730° F. and cast at 2410° F., the chill depth was the same whether the iron was held 15 min. at 2460° F. between superheating and casting, or not.

Inoculating superheated iron with 0.5% of 80% ferrosilicon reduced the increase in chill depth due to superheating. When graphite was used as the inoculant, however, the chill depth was decreased much more in superheated metal than when not superheated, and when as much as 0.6% graphite was used the chill

*Digest of "Factors Influencing the Chilling of Cast Iron", by W. J. Williams, *Metallurgia*, Vol. 51, June 1955, p. 273-279.

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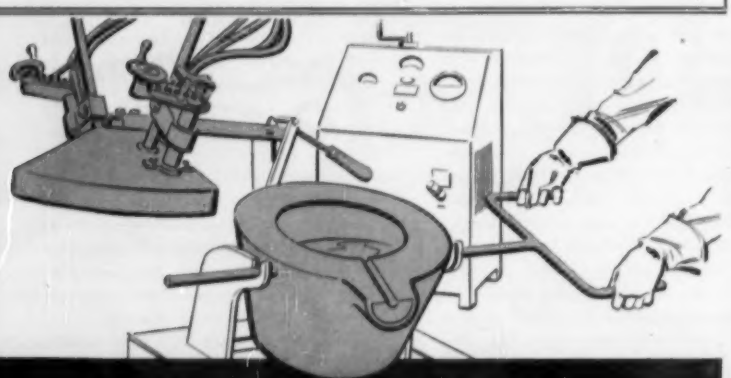

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Cast Iron . . .

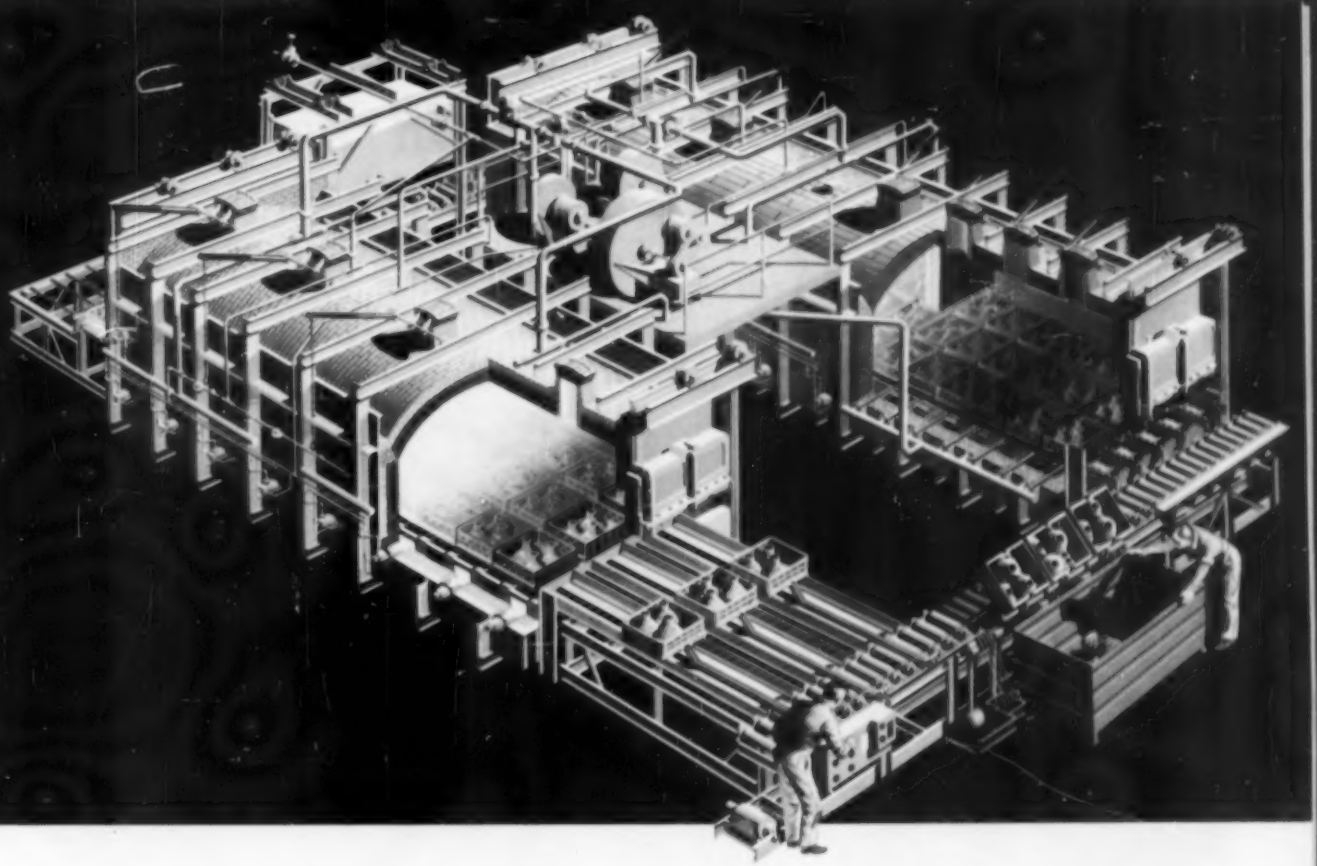
depth was the same whether superheated or not. Thus, inoculation with graphite eliminates the effect of superheating, whereas inoculation with ferrosilicon does not.

Lowering the casting temperature decreased chill depth, suggesting that the cooling rate before casting must influence the chill. (The author further states that this is true only with normal manganese and silicon contents; when they were low, the effect of casting temperature on the chill was erratic.) Rapid cooling of the molten iron in a small ladle decreased the chill slightly, as compared with the same iron poured into a hotter ladle. Inoculation with either graphite or ferrosilicon did not change this result. Superheating and casting at a high temperature produced the greatest depth of chill.

A melt of cast iron was heated to 2460° F. and half was cast in sand to produce gray iron while the other half was cast in chills to produce white iron. Both kinds of iron were then remelted, and chill tests were cast at 2410° F. after heating to 2460 and 2730° F. respectively. The fracture photographs show that the gray melting stock, although the same composition as the white melting stock, had slightly greater graphitizing ability, or less chill, at both melting temperatures, probably because of the fact that the graphite nuclei persist in the gray iron even after melting.

About 0.001 to 0.002% oxygen was found in these irons and differences in the shape of the sulphide inclusions were thought to be due to oxide contamination. Large angular sulphides change to a thin elongated type after superheating above 2550° F. Small additions of Al, FeSi or CaSi change the sulphide form to groups of fine globules. Addition of 0.004 to 0.012% aluminum to iron superheated to 2730° F. appeared to increase the depth of chill slightly. This is thought to be due to deoxidation, which leads to the deduction that, contrary to American opinion, oxygen must have a slight graphitizing effect. Small additions of FeSi or CaSi, acted like aluminum. It is admitted, however, that larger additions of Al, FeSi or CaSi reduce the depth of chill.

G. F. Comstock



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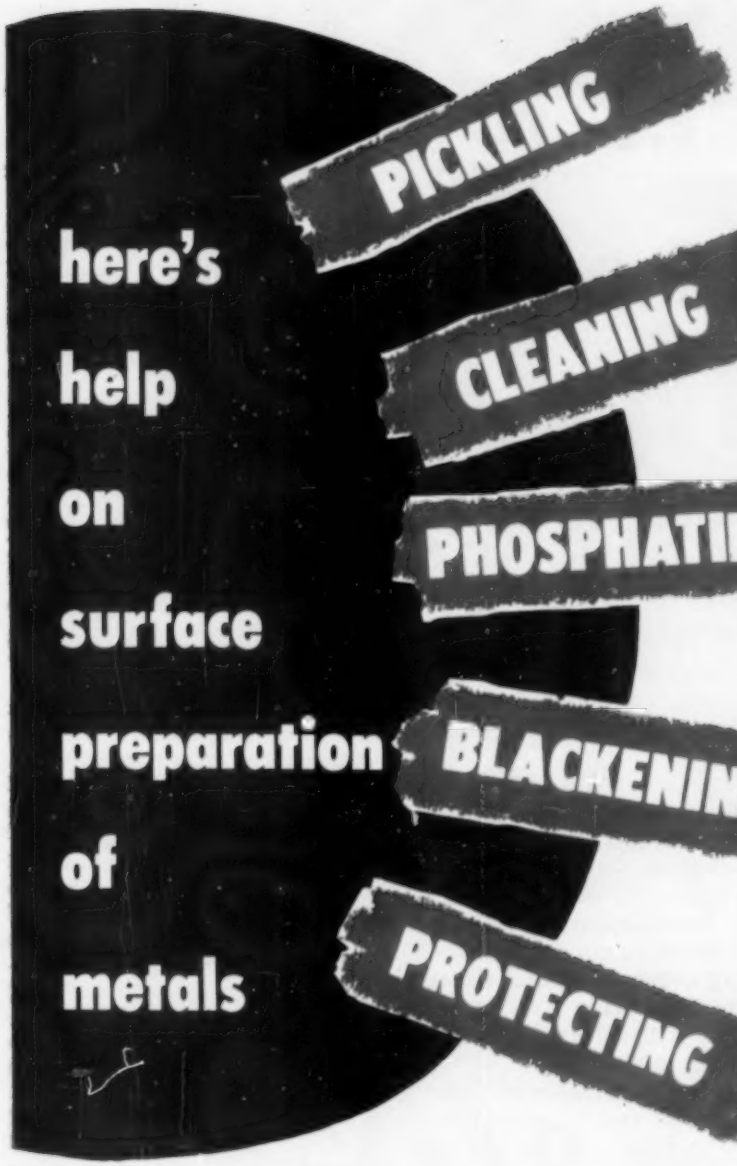

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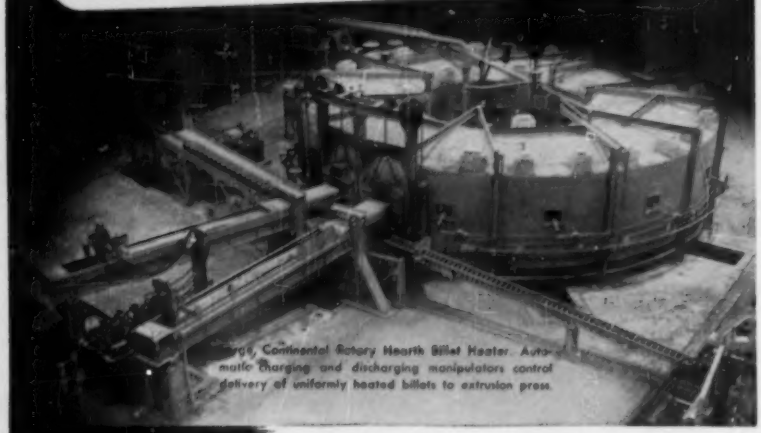

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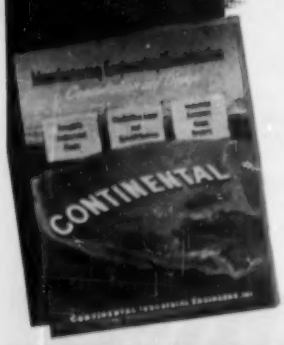

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Inhomogeneity in Plastic Working*

ROLLING, extrusion or wiredrawing may deform the metal more severely in one direction than in another, which would affect the properties and behavior in service. The effect can be either advantageous or detrimental. For example, the tensile strength of drawn brass wire is increased by an increase in the angle of the drawing die due to a greater inhomogeneity of deformation with the higher-angle die. On the other hand, plastic working can leave residual stresses as the result of inhomogeneous deformation.

Research has demonstrated the existence of inhomogeneous deformation in soft nonferrous alloys; however there is little of a quantitative nature to relate the degree of inhomogeneity to the conditions of plastic working.

By determining the variation in microhardness across the thickness of a worked material, it was felt that a reliable measure of the inhomogeneity of deformation could be obtained. Such readings were made on copper, 70-30 brass, commercially pure aluminum and mild steel in strip form, and copper and mild steel in wire form.

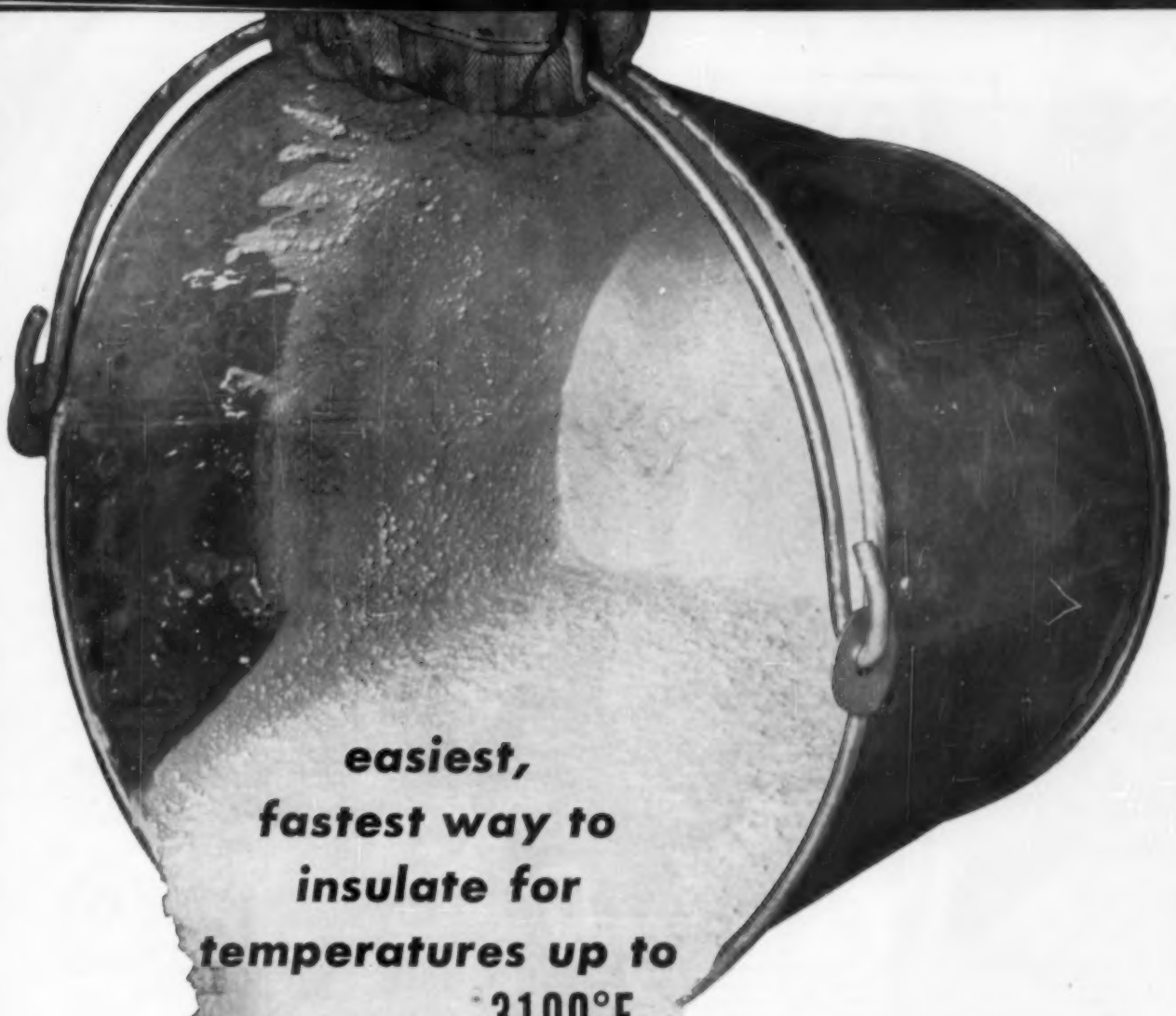
The degree of inhomogeneous deformation can be given a numerical value by expressing the difference in hardness beween the core and the surface as a percentage of core hardness. This value has been designated "inhomogeneity factor".

Reductions up to 13% (for copper) cause preferential work hardening of the surface layers. Most hardness traverse curves are not smooth, there being superimposed on the main effect a "secondary" inhomogeneity in the form of two small protuberances on the curve, between the core and the rolled surface.

When measurements were made immediately after rolling mild steel, appreciable inhomogeneity occurred but this disappeared after aging for a few days at room temperature. Further investigation of this phenomenon is in order.

A number of variables affect in-

*Digest of "Inhomogeneous Deformation in Rolling and Wire Drawing", by B. B. Hundy and A. R. E. Singer, *Journal* of the Institute of Metals, Vol. 83, May 1955, p. 401-407.



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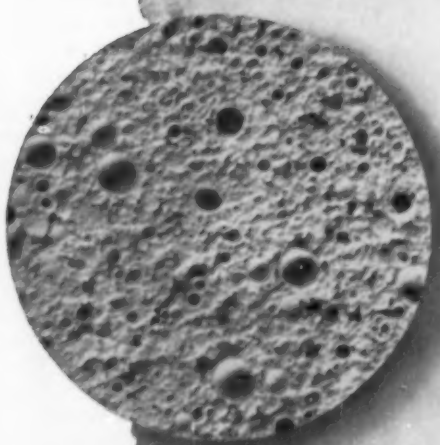

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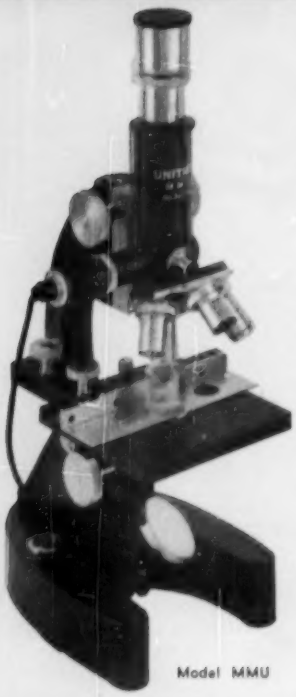
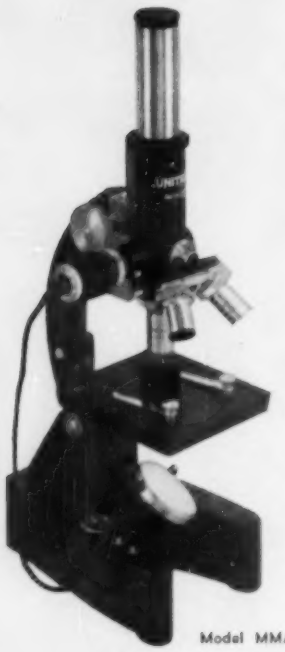


Model MMU



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MM-MP-D

Plastic Working . . .

homogeneity during rolling and wire-drawing: prestraining for higher yield strength; frictional conditions during rolling; rolling speed, stock size, reduction by several light passes instead of a single heavy pass; and reversal of direction in multiple-pass rolling.

It is possible to control to some degree the amount of inhomogeneity in rolled or drawn metals. With copper and brass, surface hardening is significant only at low reductions and can be reduced by better lubrication or by reversing the direction of deformation after each pass. No surface hardening is apparent in strain-aged mild steel or heavily worked copper, and secondary inhomogeneity appears to have a relatively minor effect on mechanical properties compared with the effect of total plastic deformation.

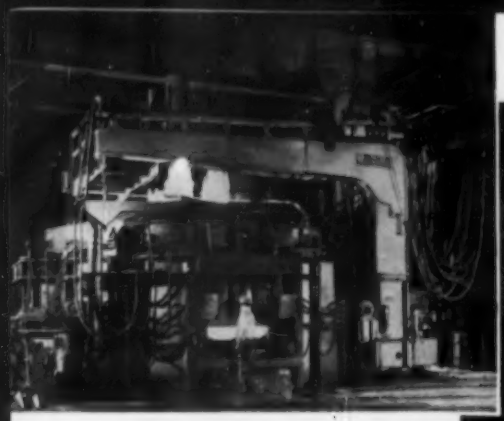
A .H. ALLEN

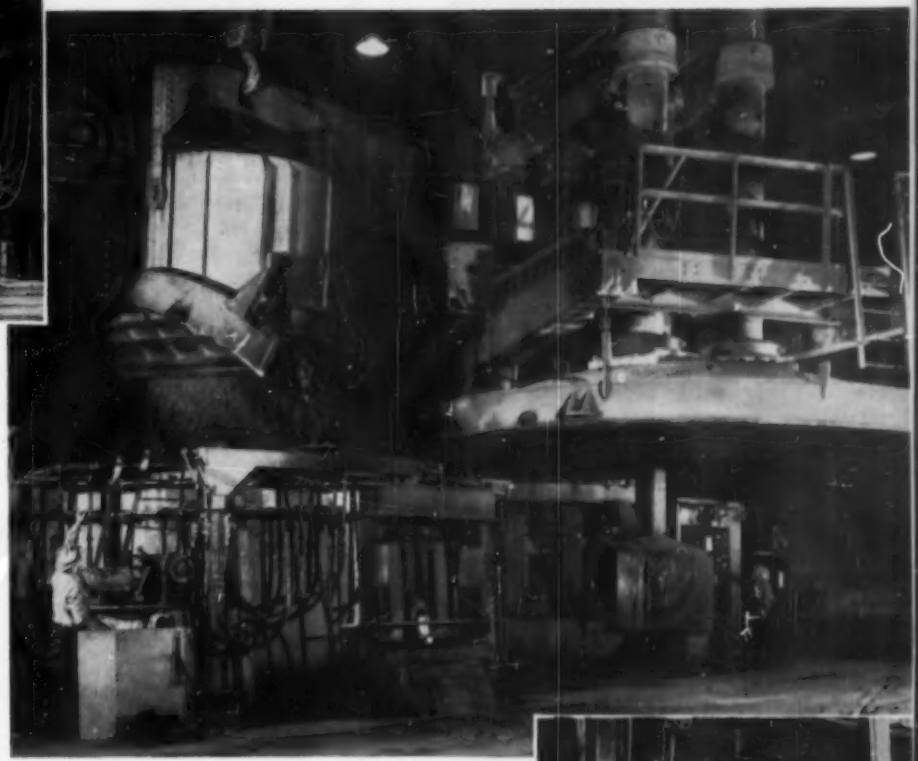
Mechanism of Hydrogen Embrittlement in Welds*

HYDROGEN in arc welded joints may contribute to such defects as underbead cracking, fissures, weld embrittlement, loss of ductility and even hot cracking. Early studies of the welding of high-tensile steels disclosed that hot-zone cracking is the result of the dissociation of hydrogen-containing compounds in the electrode coating to form atomic hydrogen, and the solution of the latter in the molten weld metal pool. While cooling, the solubility of hydrogen drops sharply at the gamma-to-alpha transformation temperature, leading to ejection of hydrogen from the lattice.

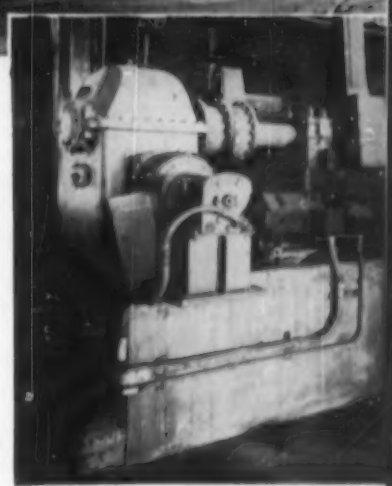
Islands and films of retained hydrogen-enriched austenite transforming at or near room temperature into hydrogen-embrittled martensite can be prevented by retarding the cooling rates of welded joints through preheating, to facilitate the diffusion of hydrogen from the junction zone. In some applications the presence of iron oxide is considered advantageous because it reduces the

*Digest of "Notes on the Role of Hydrogen in Metal Arc Welding", by P. D. Blake, *Welder*, Vol. 24, January-March 1955, p. 14-20.





Shown above is a 20′ diameter shell Top-Charge Heroult Furnace. At right, the same furnace is shown with swing-type roof removed for charging. Smaller picture at lower right, shows tilting mechanism for 20′ diameter Heroult.



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To keep pace with modern steel making methods . . . to produce better quality steel faster, and more economically, it will pay you to consider the addition of electric furnaces to your existing facilities.

In the light of the experience of some of the nation's most successful mills, Heroult Electric Furnaces should easily prove a big time and labor saver, *and quality up-grader* for you.

Embodying the latest in mechanical and electrical equipment, these widely used furnaces are noted for their efficient performance, and low operating and maintenance costs.

Available in sizes of shell diameter ranging from 7′0″ up to 24′6″, and with rated charge capacity of from 8000 lbs. up to 400,000 lbs. They are usually equipped with roof-moving mechanism to permit top charging. Both gantry and swing-type roof-moving mechanisms are available. Door-charging furnaces and furnaces of special design, including units equipped with austenitic steel bottoms to permit inductor stirring, can also be supplied.

We welcome an opportunity to help you select and install the Heroult Electric Furnace best suited to your particular requirements.

THIS CATALOG

contains up-to-date information on Heroult Electric Furnaces — types, sizes, capacities, rating, etc. For free copy, write to our Pittsburgh office.

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UNITED STATES STEEL

GET THE GAS OUT...

The Kinney Mobile Vacuum Degasser brings the advantages of vacuum metallurgy into the foundry. Here's what it will do for you by removing gaseous inclusions from melts:

- Improve density and physical characteristics of castings . . . lower rejections, build profits.
- Eliminate chemical and gas flushing.
- Let you use lower grade metals.
- Eliminate costly impregnation processes.

The rugged design of the Kinney Mobile Vacuum Degasser assures any user of dependable, trouble-free service . . . and no skilled operator is needed. The vacuum chamber is proportioned and designed for easy melt control and observation. Rapid operation is achieved by a Kinney Model KDH-130 High Vacuum Pump which is gas ballasted to eliminate vapor problems.

Write today for Bulletin 402: Kinney Manufacturing Division, The New York Air Brake Company, 3584 Washington Street, Boston 30, Massachusetts.

Kinney

Embrittlement . . .

hydrogen content of welds by oxidation of hydrogen present over the molten weld metal.

Initially, in any welded joint, there is a hydrogen concentration gradient which falls uniformly from a maximum in the weld to the original content of the plate material just beyond the heat-affected zone. With ferritic deposits hydrogen is ejected on cooling and diffuses both toward the surface and toward the lower concentrations of the heat-affected zone. With austenitic weld metal, much of the hydrogen is retained in solution and there is less diffusion to the hot zone.

Fissuring, or fine hairline cracks, in multilayer weld deposits has been ascribed to a buildup of hydrogen pressure due to its migration from previously cooled layers into the temporarily austenitic part of succeeding runs. It can be prevented by the use of low-hydrogen coated electrodes and the addition of small amounts of molybdenum, chromium and vanadium to the deposit, if high nitrogen is a contributory cause.

Normal range of weld cooling rates is between 2 and 54° F. per sec. at 570° F. Tests have shown that at cooling rates below 5 to 8° F. per sec. at 570° F. no cracking occurred, even with fairly high hydrogen content in the weld metal.

At the temperature at which hot cracking occurs, all steels are in the austenitic condition. It may be possible that, because of the sharp drop in solubility which occurs at the liquidus point, hydrogen in excess of the solubility at the melting point may temporarily develop a high internal pressure as the temperature falls rapidly toward 2000° F. This pressure will cause hot cracking if the weld is restrained. The fact that 25-20 Cr-Ni steel is more prone to this form of cracking than 18-8 demonstrates the importance of alloy content which also affects hydrogen solubility and diffusibility.

Where weld fissuring takes place below 1100° F., the direct effect of the drop in solubility of hydrogen in iron at the gamma-to-alpha transformation is evident.

Hydrogen content is only one factor contributing to weld fissuring; the others are alloy content, weld restraint, cooling rate and transfor-

THESE BEAMS ARE OF EQUAL STIFFNESS. Relative Stiffness in Bending, based on rectangular beams of constant width and equal weight: STEEL 1.0; ALUMINUM 8.9; MAGNESIUM 18.9.

Maximum stiffness with minimum weight

Of all structural metals, magnesium has the highest stiffness-to-weight ratio.

Modulus of elasticity for magnesium is 6.5 million pounds per square inch; for aluminum 10 million; and for steel 29 million. Stiffness is resistance of a material to deflection under a given load within the elastic limit. The amount of such deflection is proportional to the amount of inertia of the beam multiplied by the elasticity modulus of the material.

When a part previously of steel or aluminum is being redesigned for magnesium, the moment of inertia must be increased in proportion to the lower elastic modulus of magnesium to obtain the same stiffness. But — the moment of inertia increases as the cube of the thickness of the beam. So—very little added thickness tremendously increases stiffness. The net result is a slightly thicker section for the magnesium part, and a marked reduction in weight.

This is why magnesium is used for floor beams in airplanes; for radar feed horns and reflectors where low inertia and high stiffness are required; and for hundreds of other similar applications.

B&P engineers will help you redesign in magnesium. B&P offers the magnesium industry's most complete facilities for fabrication and assembly. Your inquiry will bring a descriptive booklet.

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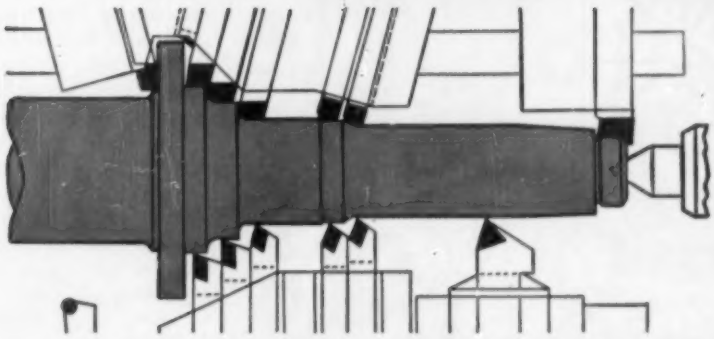

PRODUCTION RATE—UP 25%, TOOL COST—DOWN 40% AT LARGE MID-WEST TRACTOR PLANT

PART.....Shaft Steering Clutch, SAE 8654-H Brinell 370.
OPERATION.....Rough Straddle Face Flange, turn all diameters, form undercut and base.
MACHINE.....16 x 60 Sunstrand Automatic Lathe.
TOOLS.....8 Talide-tipped facing, chamfering, radius and form tools Grade 5-88. 7 Klamp-Lok Toolholders with round, triangular and parallelogram Talide inserts Grade 5-88.
DEPTH OF CUT..9/32" to 7/16"
FEED.....022
S.F.M.....156
RESULTS.....Production up 25%—Scrap and rejects down.

A FULL LINE OF TALIDE TIPS IS AVAILABLE IN OVER 1000 SIZES, STYLES, SHAPES AND GRADES—TO MEET EVERY MACHINING REQUIREMENT

NEW IMPROVED CUTTING GRADES

An extensive 2-year research and development program has resulted in a completely new and improved series of Talide Metal grades for all-purpose machining. "Double-carbides" containing tantalum carbide and tungsten carbide have been perfected for cutting cast iron and non-ferrous alloys, and "triple-carbides" containing tantalum carbide, titanium carbide and tungsten carbide for machining steels.

Major improvements have been made in our rigidly controlled vacuum furnace technique. This, along with additional refinements in our process has resulted in the creation of a carbide having a new, unique grain structure possessing harder and tougher properties than previous grades.

Laboratory tests reveal that these new, improved grades have 25% greater strength and rigidity. Extensive field tests have proven that service life per grind is increased up to 50% over previous grades. **Metal Carbides Corporation, Youngstown 7, Ohio.**

Send for new 84-page Catalog No. 55-G.

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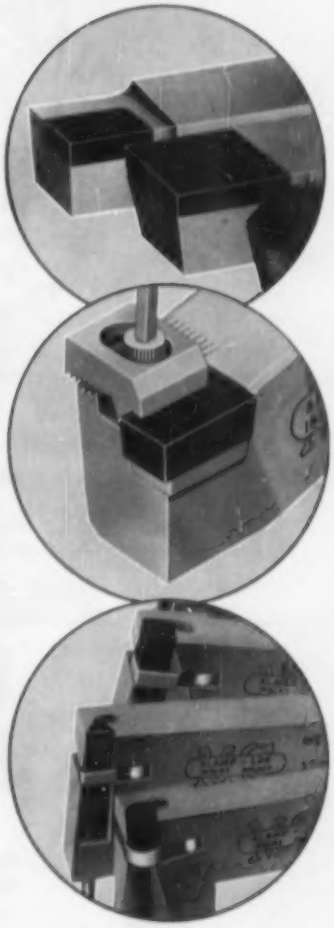

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Here at last is the truly modern flo-meter that offers important and exclusive advantages for every user.

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3. **Built-in control valves.** Operators can easily see flow change.
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For additional information request bulletin #201.

Waukee ENGINEERING COMPANY

403 E. Michigan Street, Milwaukee, Wis.

Embrittlement . . .

mation volume changes. However, hydrogen may carry sufficient weight to tip the scale in favor of fissuring.

When welds crack hours after room temperature has been reached, a time factor must be introduced. Possibly the aerostatic pressure of hydrogen, in cooperation with the other factors mentioned, was insufficient to promote instantaneous cracking. Weld restraint, delayed transformations and the diffusion of hydrogen through the steel at the slow rates possible at room temperature continue to play their parts even after the steel has cooled.

A. H. ALLEN

Evaluation of Iron-Powder Coated Welding Rods*

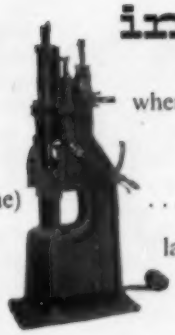
WELDMENT fabricators have been faced with the problem of whether or not they should use the iron-powder coated electrodes introduced in America in 1953 as a substitute for conventional electrodes. A new code, A.S.T.M. A 233-55 T, has been written to include these electrodes, classing them as E 6024 and E 6027. The rutile (titania) type, E 6024, was designed to replace high-titania-sodium E 6012. The iron powder, iron oxide type, E 6027, was intended to replace the conventional high iron oxide E 6020. Many advantages were claimed for the new electrodes.

Preliminary tests were made on all welding rods submitted. Quarter-inch fillet welds were made according to the vendor's recommendation and broken with a hydraulic jack. These tests revealed that the acceptable operating amperage range for the iron-powder coated rods was only half of that for the conventional electrodes – much less than recommended. Of 23 brands in all four classes five were rejected by this preliminary test.

Electrodes that successfully passed were given a more thorough evaluation patterned after the requirements of the A.S.T.M. A 233-48 T, and costing over $650. Most of the

*Digest of "Evaluating the Iron-Powder Coated Electrodes for Production Use", by Donald B. Howard, *Welding Journal*, August 1955, p. 752-758.

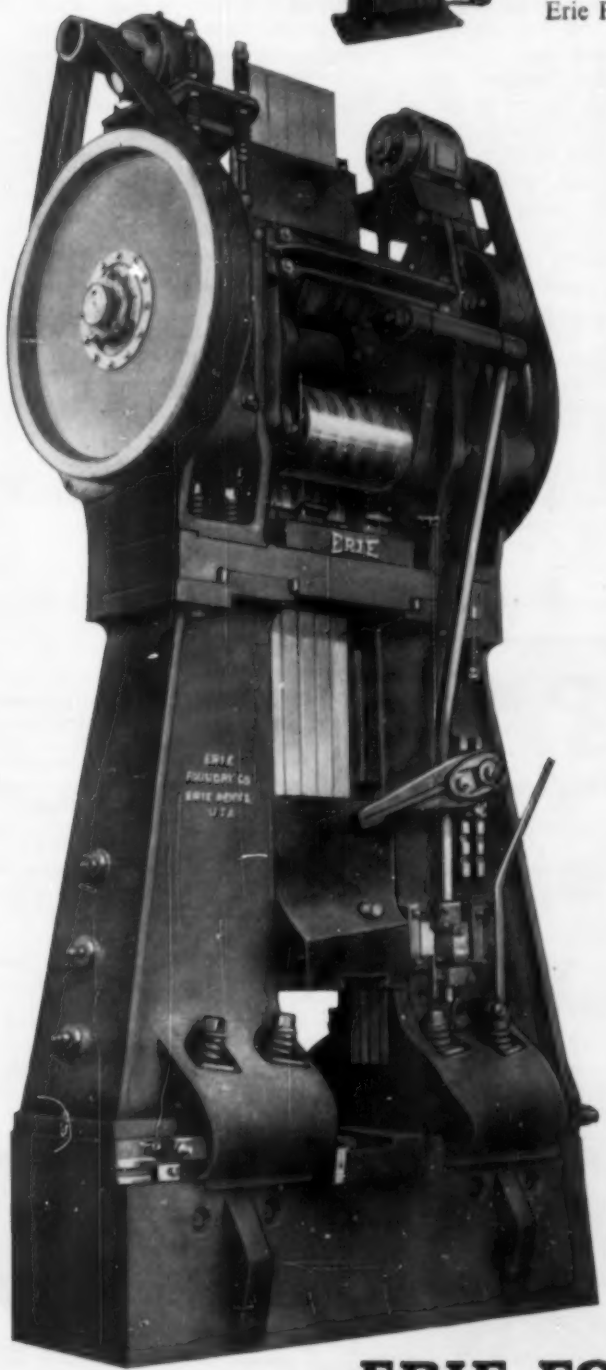
in the good old days



when Erie Foundry was *the first* to use all-steel construction in all our hammers

(such as this 100 lb. single frame)

. . . . . and when hammermen thought a board drop hammer larger than 5,000 lbs. was a wild dream . . . . even then Erie Foundry was a great name in forging hammers



today

Erie Foundry has recently built the world's largest board drop hammer. This 10,000 lb. hammer is at work for Eaton Manufacturing Co's Marion, Ohio forge plant. Eaton is forging 68 lb. net, Flat Back Ring Gears, 16" in diameter, in a single impression die, straight down without blocking or pancaking.

In addition to forging large gears speedily, Eaton likes the Erie 10,000 lb. Board Drop Hammer because the 4-roll lifting head gives longer board life. Air operated board clamps ease the hammerman's job.

As in the good old days, this 10,000 lb. board drop hammer is all-steel . . . and made by Erie.

in our 60th year

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The Greatest Name in Forging Hammers

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keeping up with

SODIUM

Titanium, first produced by a sodium reaction way back in 1910, has been commercialized only within the last five years. Its properties of high strength-weight ratio and corrosion resistance are important reasons for the growing demand in military and industrial uses. Carbide & Carbon and I.C.I. — the two newest producers — are using sodium routes. U.S.I.'s versatile metal offers cheaper, safer, easier processing than the original magnesium method of commercial manufacture.

NONE OF THE OLD OIL

Contrary to a common impression, commercial sodium *is not* handled, stored or shipped under oil. U.S.I. ships sodium metal as dry bricks, in steel drums, and cast solid in drums and tank cars. Sodium bricks are handled safely in air. In fact, bricks are molded in the open because sodium does not burn below 120°C—(M.P. 97.5°C).

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Welding Rods . . .

work was completed before the final acceptance of the new code. The variations introduced in this new tentative code (55 T) were thoroughly investigated. Nine brands of conventional and nine of the new rods were completely evaluated. Four of the conventional and only one of the new rods were approved for unrestricted use.

All-weld-metal tension tests proved to be the key to objective evaluation for all electrodes tested. They compare the yield strength, tensile strength and elongation of weld metal of competitive electrodes. The tensile and yield strengths were easily met by most brands. When the provisions of 48 T were followed, the average E 6024 elongations were 10.8%. Interlayer temperature control, which keeps the test plates near 212° F. during welding, and artificial aging (210° F. for 36 hr.), as specified in 55 T, raised this to an average of 27.8% on samples tested.

It was observed that: (*a*) The two competitive electrodes were consistent, (*b*) interlayer rather than interpass temperature control raised elongations about 30%, (*c*) artificial aging raised elongations even more. Most of the specimens from unaged welds made with iron-powder coated electrodes broke in an irregular brittle manner. The fracture face invariably contained "fish eyes" which are associated with hydrogen. Aging reduced this condition.

Guided-bend tests proved to be the least critical of the tests used in the evaluation. Their importance

Comparative Welding Characteristics, Maximum Values

	Rutile Type		Iron Oxide Type	
	E 6012	E 6024	E 6020	E 6027
Burn-off rate, in. per min.	10.3	14.2	12.3	13.0
Speed, in. per min.	10.2	13.9	12.5	15.2
Deposit rate, lb. per hr.	8.4	15.2	9.5	9.9

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a single, central instrument
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at up to 23 locations

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HIGH RESISTANCE INDICATING PYROMETERS

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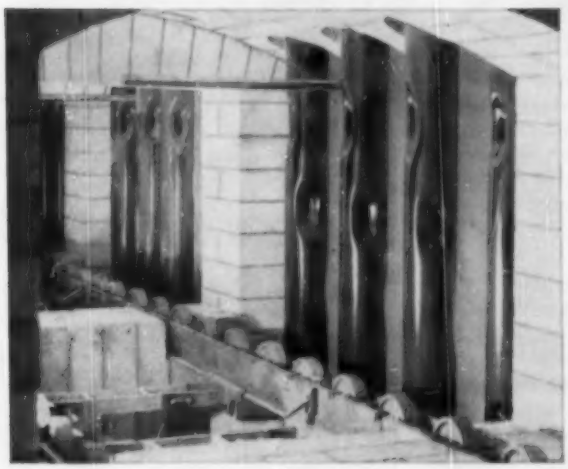

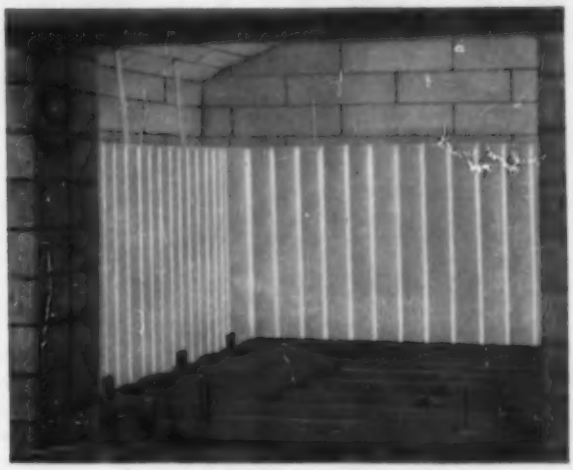

. . . IN THE GAS-FIRED FURNACE

NEW LINDBERG VERTICAL RADIANT TUBE

Because of its revolutionary design, this tube provides a new level of gas-fired furnace performance. The secret lies in the new Lindberg tube's "dimples." The tube carries a central stream of mixed air-and-gas surrounded by a cylindrical stream of air alone. Combustion occurs in the area between these two streams. The "dimples" create eddies accelerating combustion and maintaining even temperatures along the entire tube.

This Lindberg tube will operate at maximum efficiency for a longer period of time. The special protective coating gives greatest possible resistance to carbon penetration. Vertical position eliminates soot deposit and resultant temperature increases at points of sooting.

Tubes are 59 inches long, weigh only 29 pounds, changeable in a few minutes. No costly furnace shutdowns nor high labor and material cost for tube changes.

. . . IN THE ELECTRIC FURNACE

NEW LINDBERG CORRTHERM ELEMENT

CORRTHERM, Lindberg's radically advanced new electric heating element offers advantages never before available for heat treating furnaces. With this new element carburizing and carbonitriding with electricity becomes practical, efficient and economical. Ideal, too, in other types of Lindberg electric furnaces.

The outstanding feature of the CORRTHERM element is the extremely low voltage at which it operates. Consequently, leakage through carbon saturation and shock or short hazards are eliminated. Elements also act as baffles to direct circulation of convection streams.

CORRTHERM elements are practically indestructible. Work load or operator's charging tool can't hurt them. Watts density is at all time low. Easily installed or replaced, too, as element merely hangs in furnace and no complicated mountings are required.

Lindberg Field representatives in 21 cities are ready to show you how Lindberg furnaces with these revolutionary new elements can improve your heat treating process. You'll find your Lindberg representative's name in the classified section of the phone book or write us direct

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Luster-On products are manufactured on the West Coast by Crown Chemical and Engineering Company of Los Angeles, Calif., and in the Dominion of Canada by Alloycraft Limited of Montreal, Quebec.

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THE Chemical CORPORATION
70 WALTHAM AVENUE
SPRINGFIELD, MASS.

Welding Rods . . .

cannot be underestimated when considering weld soundness for production fabrication.

Macro studies revealed the degree of penetration, soundness and extent of the refining effect of subsequent passes on previous deposits.

Rockwell "B" hardness surveys were made from base metal, through the heat-affected zone to the weld, including root, intermediate and cover passes.

Micro-examination on unetched and etched specimens showed an acceptable and normal frequency of nonmetallic oxide inclusions.

Impact tests were made using Charpy keyhole bars at 70 to –100° F. These were compared with results "to be expected" in the appendix of specification 55 T.

Advantages in speed of the new electrodes are shown in the table on p. 194.

The iron-powder coated electrode is here to stay. Rapid improvement has been noted in the performance of electrodes produced by some manufacturers when compared to those initially offered for testing just over a year ago. The user must be willing to get the facts himself by analyzing his own use and design. Desirable features have been observed in the laboratory for each of the iron-powder coated electrodes. It is hoped that these features can all be incorporated into one electrode in the near future.

The only police force assuring consistently high quality is the manufacturer. Several reputable vendors admit that they check their products against specifications only once a year.

DAN WHITE

REVIEWER'S COMMENT – It would appear that the use of an excess of iron powder in the electrode coating became popular in Italy primarily because the powder cost less per pound than the wire! When the idea was tried in America, where the relative costs are just the opposite, it was found that current densities could be largely increased with corresponding increases in the rate of deposition. This decreased the cost for welder's labor (the expensive item over here) much more than the premium which had to be paid for the metal powder.

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Lithium Ingots are used in the degasification of copper. Lithium Cartridges are used in the refinement of high temperature copper, and in brass, bronze and nickel-silver castings. Even the salts of lithium (Carbonate and Chloride, specifically) hold great promise for heat treating.

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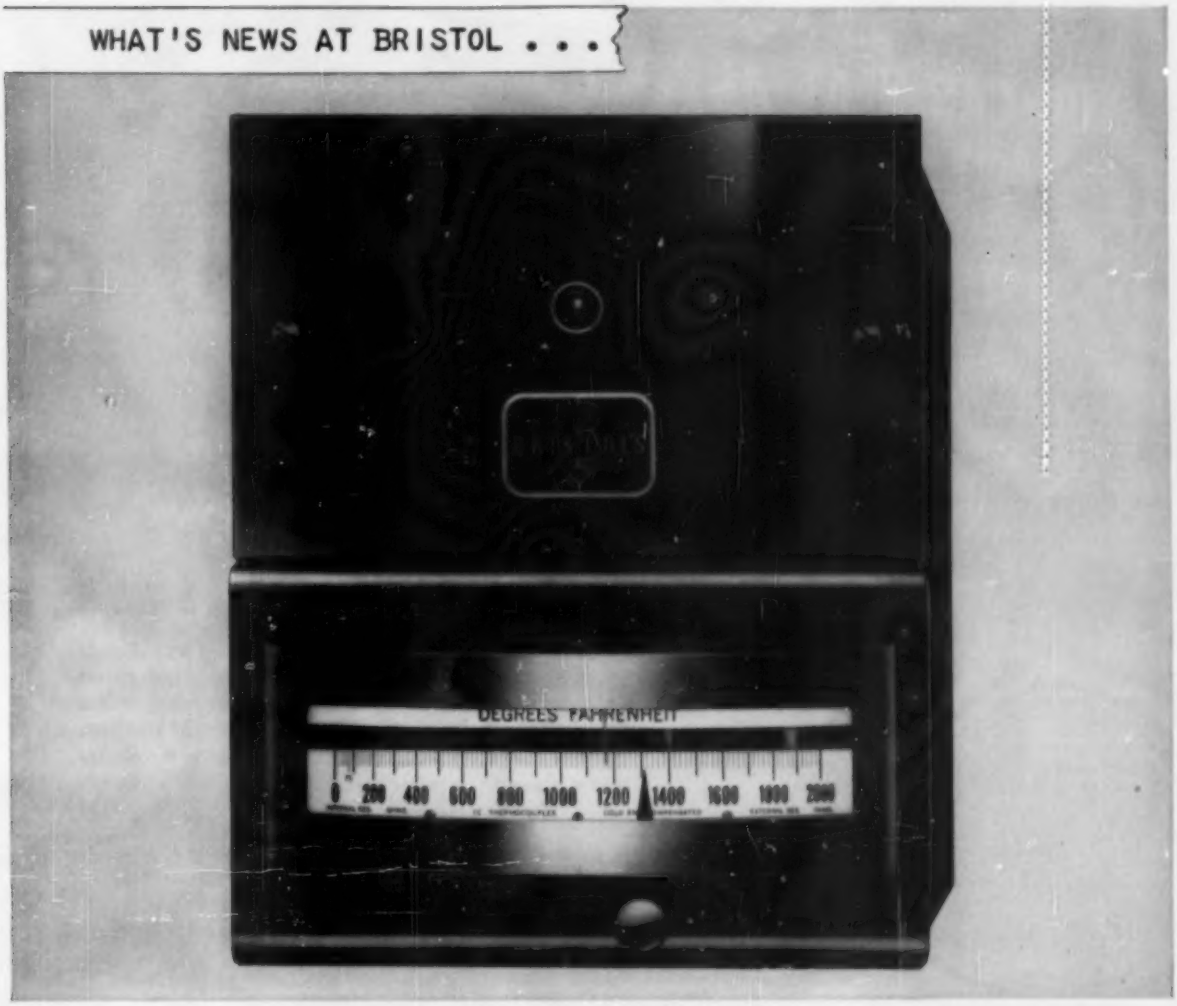
WHAT'S NEWS AT BRISTOL . . .



Thyratron-operated relay gives you closer control with this Bristol temperature controller

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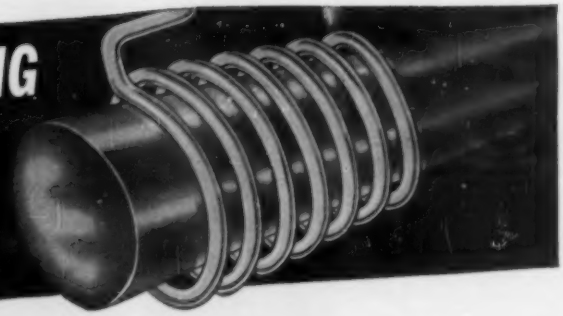

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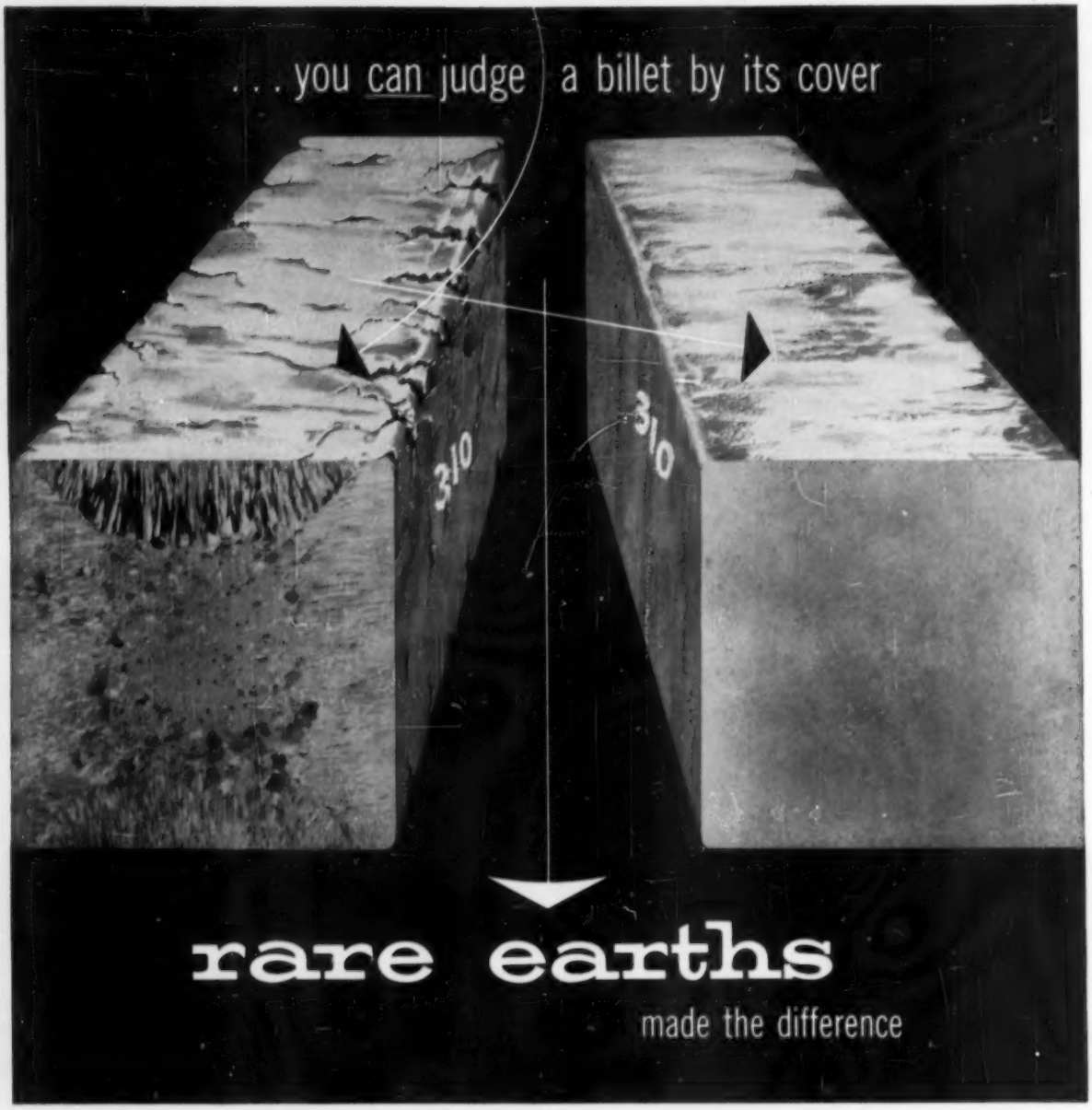

The two billets shown were produced by a prominent manufacturer of 310 stainless steel. Before rare earth additions, the billet on the left shows a coarse columnar structure, with frequent corner cracks. Heavy cogging was necessary to permit rolling with a minimum of hot tearing; after rolling a grinding loss from the edges incurred additional production time and expense.

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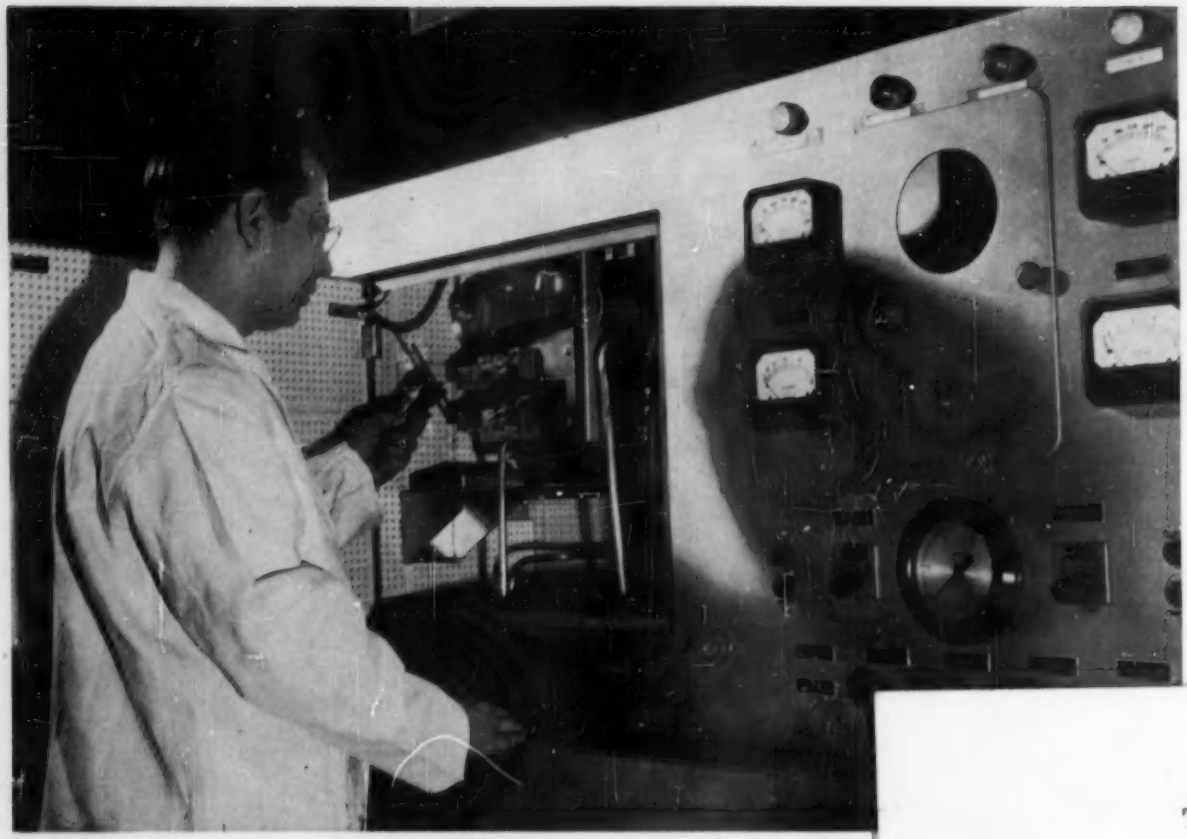

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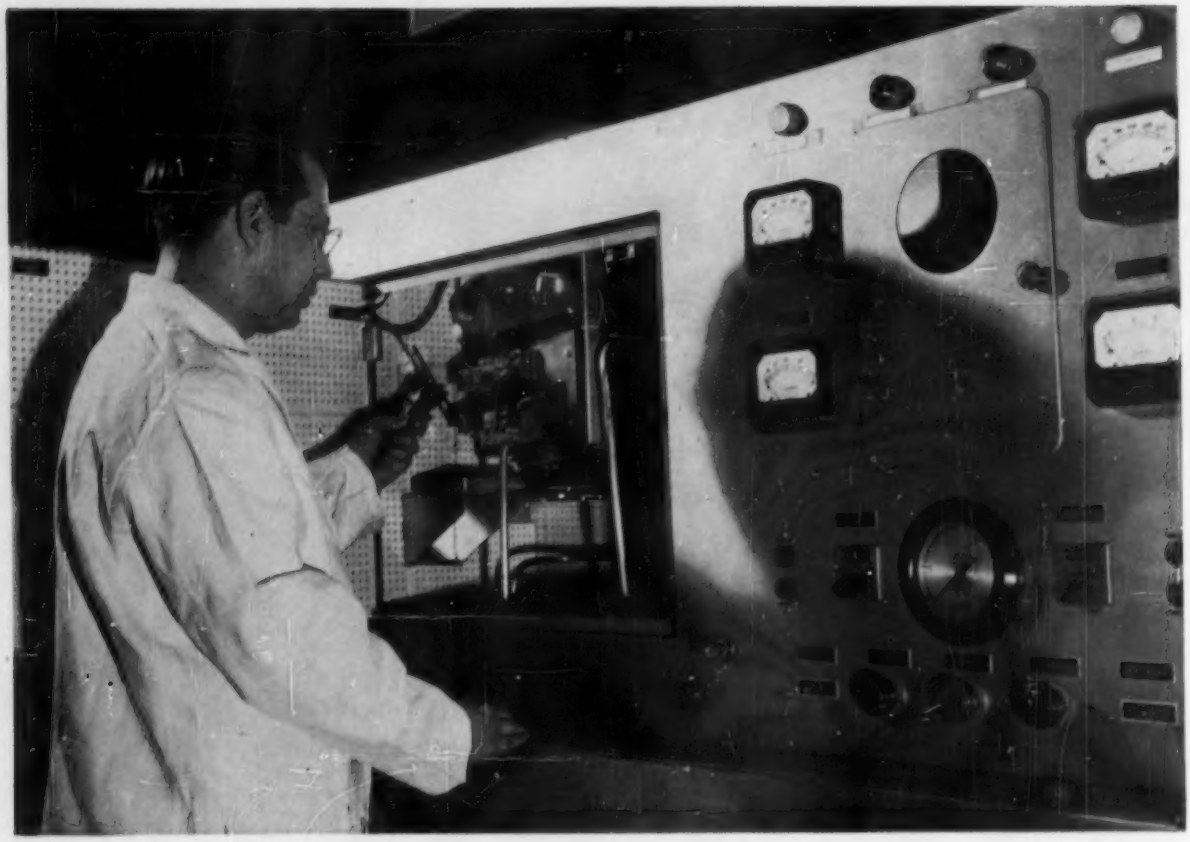

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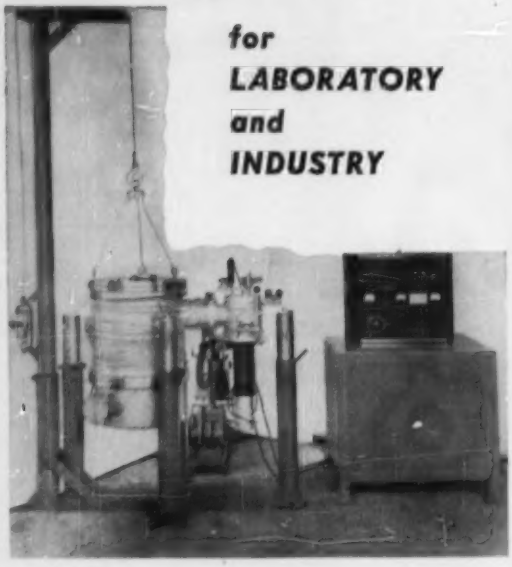

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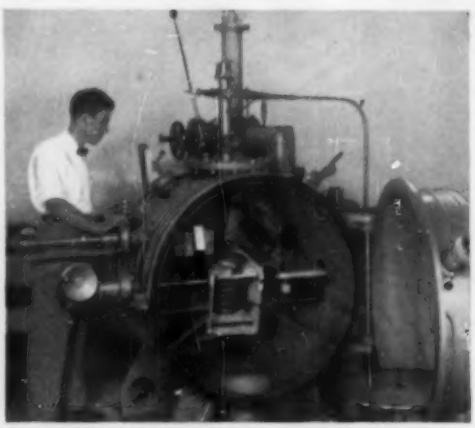

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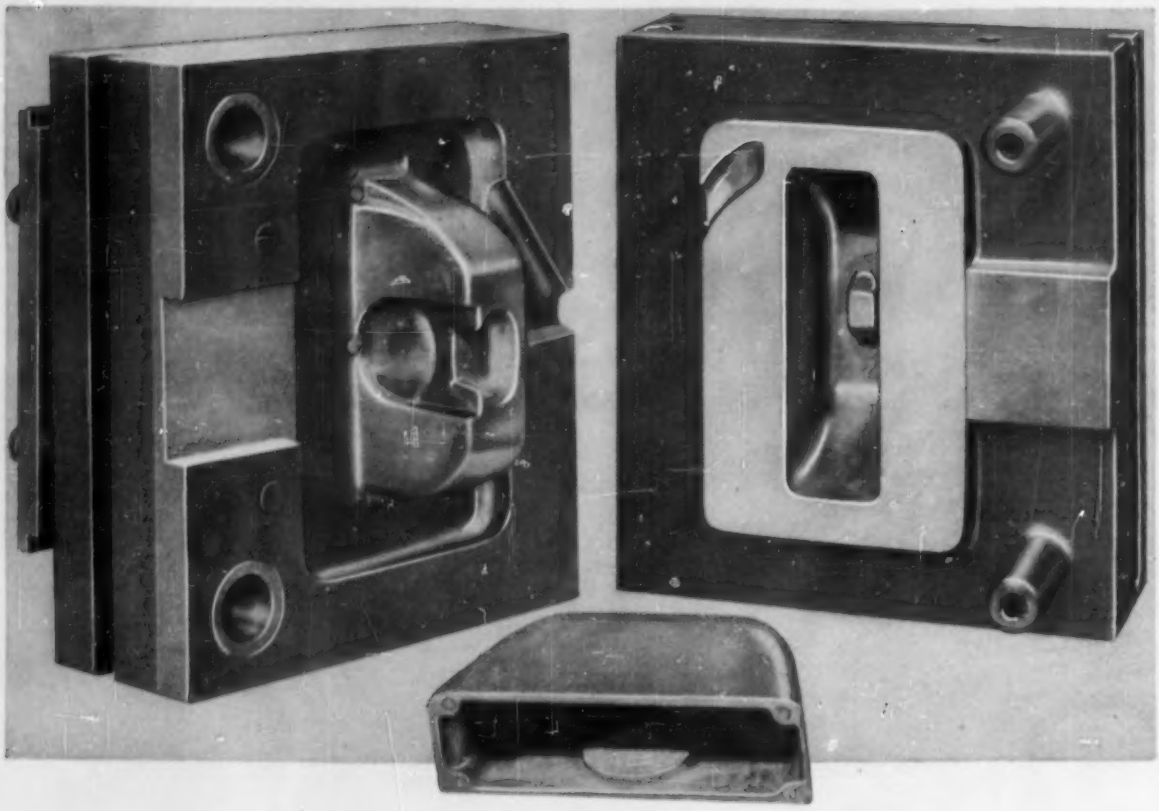

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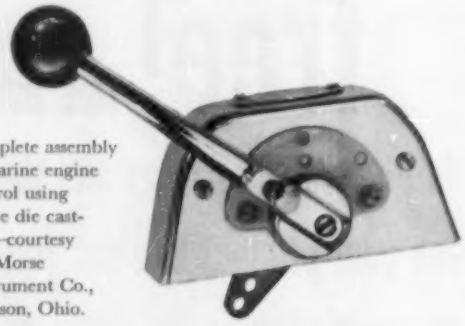

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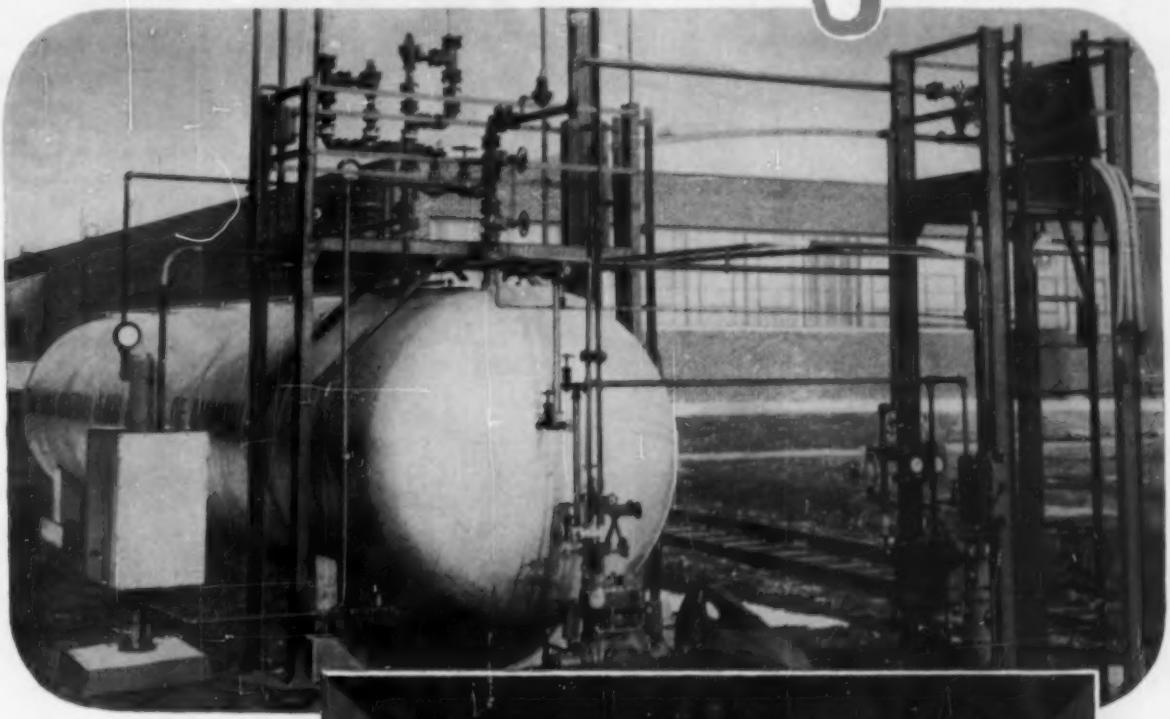

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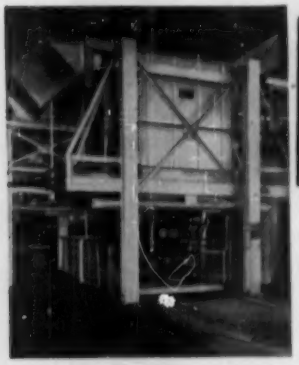

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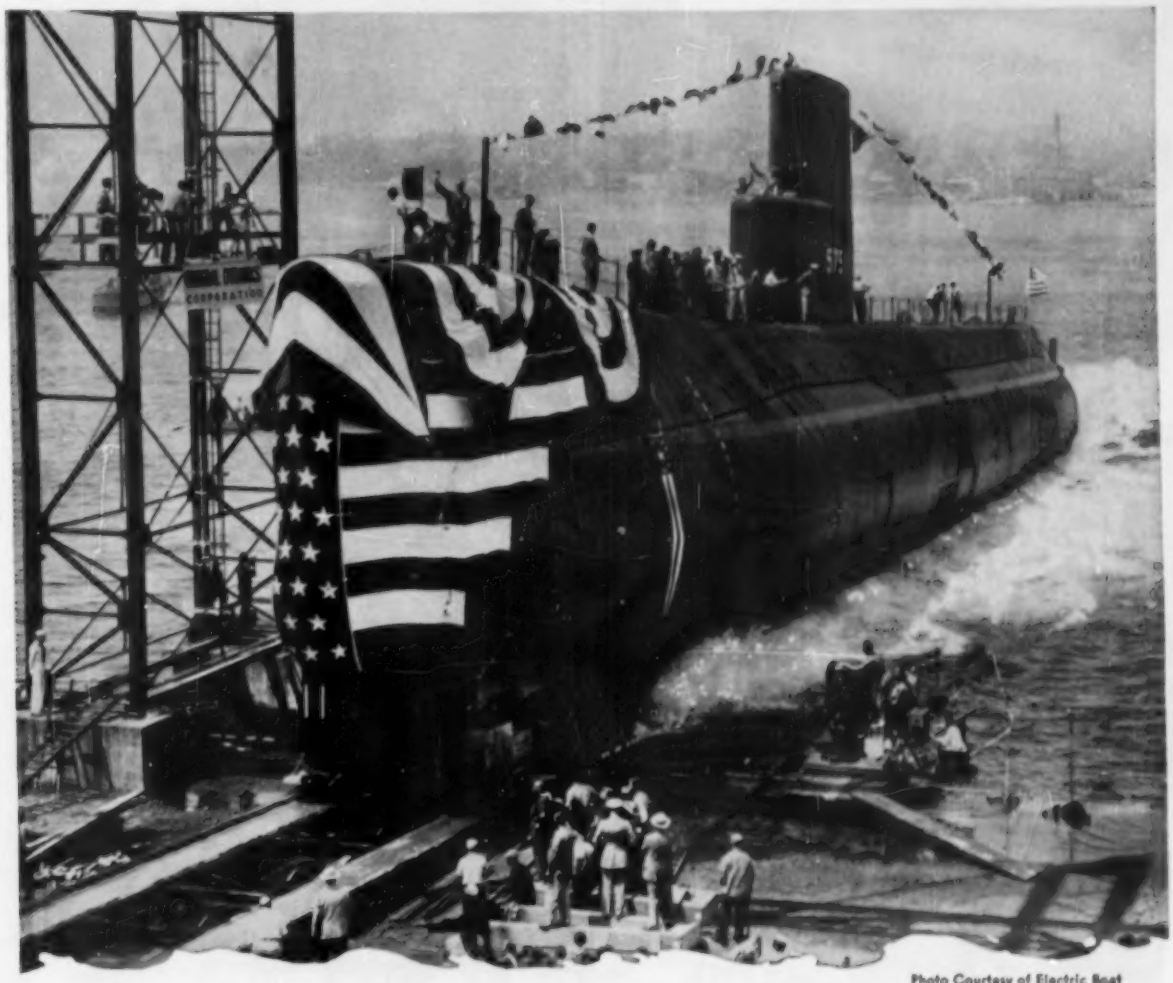

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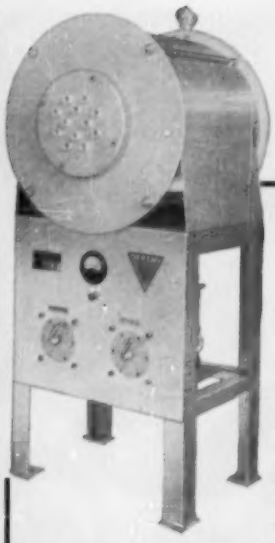

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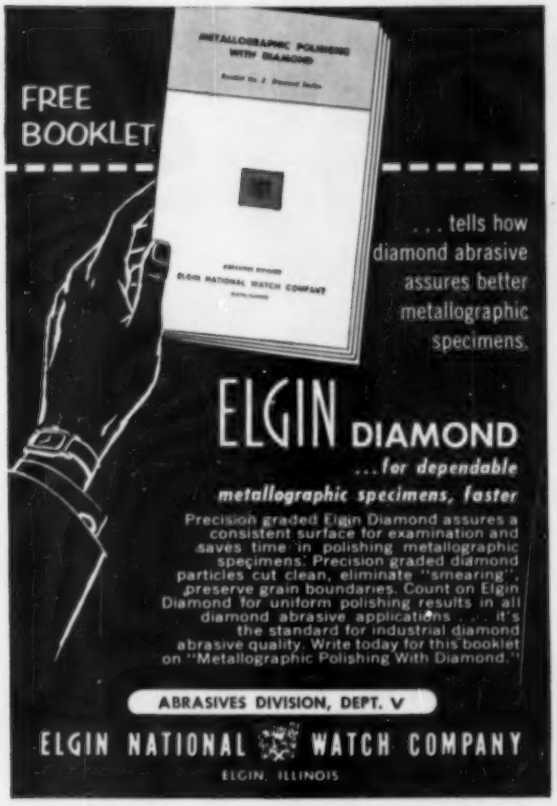
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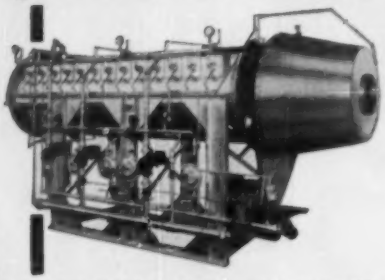

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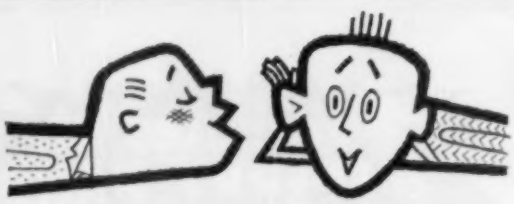

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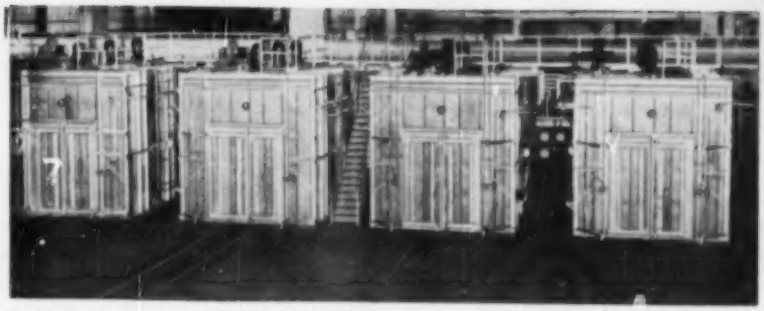
EF aluminum brazing and heat treating furnace in which assemblies are advanced thru three separate chambers, on trays, for brazing, solution treatment and forced cooling.



Part of an installation of large EF multiple zone batch truck type direct gas fired units with recirculating fans for uniformly aging aluminum forgings, etc.

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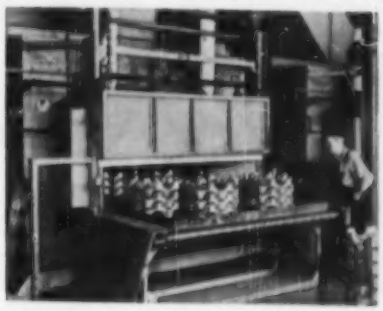
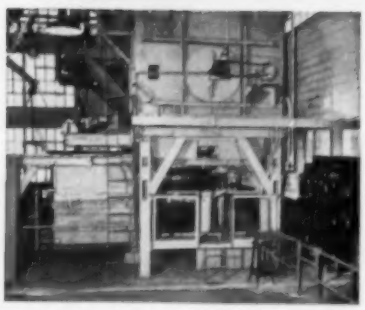
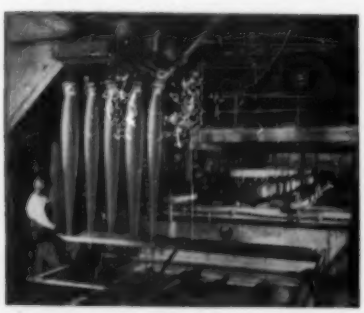


EF combination gas fired, radiant tube and electrically heated roller hearth type furnace used for heat treating aluminum alloy crank case sections, pistons, etc.



EF electrically heated, accurately controlled forced circulation, bottom door opening elevator type installation for aging, annealing and solution heat treating aluminum and aluminum alloys.



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